MODERNITY AND THE SPIRIT OF THE SEA: MARITIME INFLUENCES ON EARLY MODERN ENGLISH STATE INSTITUTIONS AND SOCIETY, 1485-1763

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MODERNITY AND THE SPIRIT OF THE SEA:
MARITIME INFLUENCES ON EARLY MODERN ENGLISH STATE INSTITUTIONS AND SOCIETY, 1485-1763

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Dr. John Krige, School of History and Sociology, *Georgia Institute of Technology*

Dr. Krige has acted as my advisor since I started this program seven years ago. I owe my understanding of the interaction of history and technology to him. Even though we have had spirited disagreements on just about every aspect of the canon, I have truly enjoyed the dialogue. Dr. Krige is the archetype of what a college professor should be, informed, open minded, tolerant, and Socratic. Dr. Krige also advised me through my first independent research on the Age of Exploration. He directed me to the cutting edge scholarship in the field and even arranged lectures and meetings with leading scholars like Dr. Alison Sandman. He introduced me to the research of Larrie D. Ferreiro, Nicolás Wey Gómez, and William M. McBride, to name just a few of the authors referenced herein. Lastly, he has been instrumental in helping to narrow an overly broad area of interest into a more targeted thesis. It was his insight to observe the evolution of modernity and modern state institutions in England through a 'maritime lens' and that is specifically what this work attempts to do.

Dr. John Tone, School of History and Sociology, *Georgia Institute of Technology*

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Dr. Nick Wilding, History Department, *Georgia State University*

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Dr. Carla Gerona, School of History and Sociology, *Georgia Institute of Technology*

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I would be greatly remiss if I did not express my warm appreciation for all of the help LaDonna Bowen has given to me over the last seven years. Her regular assistance in registering classes, completing the Masters application, arranging comprehensive exams, and assembling the dissertation committee and its various reviews and meetings has been invaluable. She has always been helpful, cheerful, and above all patient. This is no small thing when dealing with aged graduate students.

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LIST OF ABBREVIATIONS

BOE	Bank of England
DD	Doctor of Divinity
EIC	East India Company [English/British]
FRS	Fellow of the Royal Society [of London]
GMT	Greenwich Mean Time
HMS	His or Her Majesty’s Ship
LOB	Line of Battle
MP	Member of Parliament
RN	Royal Navy
SP	State Papers
SSK	Sociology of Scientific Knowledge
VOC	*Verenigde Oostindische Compagnie* – Dutch East India Company
WIC	*Geoctroyeerde Westindische Compagnie* – Dutch West India Company

SUMMARY: Statement of Thesis

Renaissance Europeans developed and applied science and technology in a project of oceanic exploration, trade, and colonization, that when coupled with messianic fervor, entrepreneurial energy, and imperial ambition, changed the world. Originating in Iberia, and reaching northward through the Basque and Breton regions of France, to the Low Countries and England, the small kingdoms bounding the northwest Atlantic would struggle for global hegemony and create what we continue to think of as modernity. Much has been written about this project and the technologies developed to make the oceans navigable lines of long distance power, trade, and control. It is the purpose of this work to examine the sponsors and agents of the maritime project and their often concomitant role in creating some of the defining institutions of modernity. It is noteworthy that these institutions were not simply focused upon diplomatic, political, and military concerns, but also upon the cutting edge science and technology of each nation's oceanic program.

Modernity was not a product of the Atlantic powers maritime programs, nor was the global oceanic capabilities of these nations the inevitable byproduct of a developing modern nation state. However, the first modern nation states – centrally organized and secretive; bureaucratically controlled; invested in scientific progress for economic and political aggrandizement; capitalist; technologically dependent and adaptable; and industrial in both economics and war – were both influenced by and a source of European dominance at sea. The development of modern state institutions and large oceanic merchant and naval fleets happened simultaneously, were intricately connected and stimulated each other. The modern state and the evolving oceanic capabilities of the Age of Sail were produced together, often by the same actors, and always in conversation. We might have developed a 'modern world' without the

Atlantic maritime adventure, but neither it, nor post-Columbian history would have been the same without the reinforcing admixture of the other. Our modern world was born on both land and at sea.

It is the purpose of this work to examine the concomitant development of institutions of the modern state that emerged in the Early Modern Period, with a specific focus upon England from the Tudor dynasty through the early Georgian era. Atlantic maritime programs did not produce English modernity, but did play an integral role in its fitful emergence, especially in this most nautically focused island nation. The rewards for its maritime prominence were profound as England's naval and merchant fleets came to dominate all the earth's oceans throughout the nineteenth century.

The Early Modern English State was modernizing by creating a legally trained professionalized bureaucracy, a systemic security apparatus, large stock trading companies, a national bank on the Amsterdam model, and an empirical scientific establishment. This growth occurred in tandem with the increasing size, reach, and professionalism of England's commercial, piratical, and naval fleets. The key actors directing or swept along with these changes were often the same, but always in communication each other. The demands of the sea and this new state were in sync and accelerated each other's evolution during this period of rapid social change. This work seeks to enrich the historical canon by moving the Atlantic maritime adventure from the background in the English modernizing story to a more central position. In order to do so, we will examine a lot of old data, using a maritime lens. In order to get a better grasp of England's transition to modernity, and its subsequent global export, it is fitting to move the focus from London, or from the rising gentry, or from nascent industry, to the sea.

CHAPTER 1: INTRODUCTION

A Nexus between Early Modern Maritime Programs and Modernity?

In the fifteenth and sixteenth centuries, Europeans developed and applied science and technology in a project of oceanic exploration, trade and colonization, that when coupled with messianic fervor, entrepreneurial energy, and imperial ambition, was truly world-changing. Originating in Iberia, and reaching northward through Basque and Breton regions of France, to the Low Countries and England, the small kingdoms bounding the northwest Atlantic would struggle for global hegemony and usher in what we continue to think of as modernity.[1] Although much has been written about this project and the technologies developed to make the oceans not only passable, but into lines of long distance power, trade and control, it is the purpose of this work to examine the concomitant development of institutions of modernity that emerged during the same period and to provide the sea a central place in the story of the creation of the modern world. It is noteworthy that these institutions were not simply focused upon diplomatic, political, religious, and military concerns, but rather upon the cutting edge science and technology of each nation's oceanic program. This was especially the case in England.

The linkages between the state makers of early modern Europe, the emergence of mercantilism and then capitalism, and their maritime and colonial projects has been examined by historians, economists, and social scientists of varied pedigrees. There has been acceptance among astute observers that aggressive maritime trade was intricately tied to national wealth, technological progress, and power in the early modern period. This is not a new view. Prior to

[1] Fernández-Morera, Darío, *The Myth of the Andalusian Paradise: Muslims, Christians, and Jews under Islamic Rule in Medieval Spain*, 14-15, notes that "*Iberia* is a pre-Roman and therefore premedieval term." It is anachronistic, but sadly vogue. Although the name Spain has evolved into a specific national reference, Fernández-Morera notes that in the medieval period, Portugal, Castile, Aragon and Leon were all referred to as kingdoms in Spain – not in Iberia. These Romanized Visigoth kingdoms are more accurately referred to as belonging to Latin Hispania. However, to avoid confusion with references to the Spanish nation of the period and the other nations on the peninsula, the term Iberia will hereafter be used to refer to the collective peninsula and Spain the kingdom dominated by Castile and later by the Hapsburg monarchy.

the English rise, the Dutch turned their national energy seaward. The French Enlightenment author [Guillaume Thomas François] Abbé Raynal observed:

> "The Spaniards though possessed of all the gold in the world remained or became poor; the Dutch presently acquired riches, without either lands or mines. Holland is a nation at the service of all the rest, but who sells her services at a high price. As soon as she had taken refuge in the midst of the sea, with industry and freedom, which are her tutelary gods, she perceived that she had not sufficient quantity of land to support the sixth part of her inhabitants. She then chose the whole world for her domain, and resolved to enjoy it by her navigation and commerce. She made all lands contribute to her subsistence, and all nations supply her with the conveniences of life."[2]

Raynal's is not just a statement about the declining fortunes of an aging regime and the wealth available to a young upstart, but rather recognition of a major paradigm shift; recognition that the world had changed forever because of the Atlantic maritime adventure and that the future – the modern – would be intricately tied to seaborne trade and global interaction. But to leave it there is to make a linear argument whereby oceanic exploration led to trade and colonialism which led to our modern capitalistic world. The real story is far more involved.

The rise of modern institutions in Europe and specifically in England were directly influenced by, and interwoven with, the national oceanic projects of the day. These new relationships among theoretical knowledge, applied science, technology, and state secrecy developed along with the Age of Exploration and with the maritime communities at its center. Like the oceanic project itself, government attempts to control one aspect of the nautical canon, cosmographic knowledge enabling sustained oceanic trade and control, and to build institutions to exploit this knowledge first emerged in Iberia. However, it was in England that the connection between modernity and the sea became most central.

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[2] Raynal, Abbé, *A Philosophical and Political History of the Settlements and Trade of the Europeans in the East and West Indies* (Amsterdam, 1770), Book XIX, 495-496, Volume V of X, translated by J. Justomond, 3rd ed. 1777.

In order to illustrate these connections it is critical to understand both the global situation in the fourteenth and fifteenth centuries and the relationship Western Europeans had with both their Mediterranean and Ottoman neighbors, and the tenuous ties Europe had with the rest of the Eurasian landmass. These connections, disruptions, and threats, when coupled with material desire and an evangelical resurgence, provided the motivation to launch Iberia, and then the rest of Western Europe onto the world's oceans. This work examines this seaward movement and begins with the Portuguese and the Castilian projects. They developed and applied the initial science and technology thought to be appropriate objects of state secrecy and which produced the state power and wealth that attracted the envious attention of their northern neighbors (France, Holland, England). The knowledge first developed and applied in Iberia was a critical focus of England's new institutions, intelligence networks, and secrecy apparatuses. This knowledge also enabled England (along with the Dutch and French) to challenge Hapsburg Spain at sea and across the globe.

It is the purpose of this work to examine the concomitant development of institutions of the modern state and society that emerged in the early modern period, with a specific focus upon England from the Tudor dynasty through the Georgian era. Atlantic maritime programs did not produce English modernity, but did play an integral role in its fitful emergence, especially in this most nautically focused island nation. The rewards for its maritime prominence were profound; as England's naval and merchant fleets came to dominate all the earth's oceans throughout the nineteenth century.

The early modern English state was modernizing by creating a legally trained professionalized bureaucracy, a systemic security apparatus, large stock trading companies, a national bank on the Amsterdam model, and an empirical scientific establishment. This growth occurred in tandem with the increasing size, reach, and professionalism of England's commercial, piratical, and naval fleets. The key actors directing or swept along with these changes were often the same, but always in communication each other. The demands of the sea and this new state were in sync and accelerated each other's evolution during this period of rapid social change. This work seeks to enrich the historical canon by moving the Atlantic maritime adventure from the background in the English modernizing story to a more central position. In order to do so, we will examine a lot of old data, using a maritime lens. In order to get a better grasp of England's transition to modernity, and its subsequent global export, it is fitting to move the focus from London, or from the rising gentry, or from nascent industry, to the sea.

Historiographical Context

Students of the history of technology have been exposed to the maxim that technology following developments in science (or philosophy or metaphysics) was a relatively new phenomenon with its roots in the nineteenth century chemical and electrical fields. Joel Mokyr, in his examination of technological development up to the dawn of the twentieth century, contends that, "it is widely believed that before the middle of the nineteenth century, technological progress moved more or less independently of scientific progress, and that since then the interaction between science and technology has gradually become tighter."[3] Technology prior to that time has been widely written about as an empirical or craft-based enterprise unrelated to the dominant epistemologies of the time. Although a great deal of early nautical technology was empirically driven, the pioneering fifteenth century Portuguese oceanic program

[3] Mokyr, Joel, *The Lever of Riches: Technological Creativity and Economic Progress*, 113, conditions his assertion with the following observation: "As we have seen, this is only partially correct. Science, and especially scientists, were [sic] not totally irrelevant to technological change before 1850." The year 1850 serves as a watershed year for historians of technology – the birth of science based industries distinctly altered their perception of technological origin. Mokyr explains that, "after 1850, science became more important as the handmaiden of technology. A growing number of technologies, from waterpower to chemicals, depended on or were inspired by scientific advances."

had scientific roots. Recent scholarship has shown that Western oceanic exploration and its derivative technologies was inextricably wedded to the early modern 'sciences' of astronomy and cosmography and appears to be one of Mokyr's rare exceptions to early technology's empirical roots. As an example, John Law illustrates this linkage in the Portuguese case:

> "In 1484 King John II convened a small commission and charged it with the task of finding a method for navigating outside European waters. … These four men, and probably in particular [Jose] Vizinho, were responsible for one of the earliest successful practical applications of scientific knowledge to practice: the *Regimento do Astrolabio et do Quadrante*."[4]

The first sustained oceanic technological success story was not just propelled by trial and error, although for decades dozens of caravel crews lost their lives in the effort. At its core, this quest had scientific paternity, and this feature would become emblematic of the modern.

Pamela Smith, in her historiographical review of the state of the history of science cites Adam Mosley's *Bearing the Heavens*, which shows that "making of astronomical knowledge was dependent on the exchange of letters, books, and instruments, and that it was collaborative, as members traded and calibrated observations, contested timekeeping practices, and argued about the shape of the cosmos and the order of the planets."[5] Their contention is that the society of astronomers created the new cosmology through the social process of debate and intercourse. Proceeding along these lines, it is arguable that one of the prime users of astronomical information, and one of the major generators of worldwide astronomical data, oceanic navigators, would be an integral part of this 'social shaping' of the new astronomy. Indeed Smith is keen to point out that users should not be ignored in preference to intellectuals when taking a holistic view of knowledge production:

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[4] Law, John, "On Methods of Long Distance Control: Vessels, Navigation, and the Portuguese Route to India," 9.
[5] Smith, Pamela H., "Science on the Move: Recent Trends in the History of Early Modern Science," *Renaissance Quarterly*, **62:2** (Summer 2009), 350.

> "Practioners of practical mathematics – surveyors, astrologers, gunners, navigators, gaugers, and teachers of the *abbaco* – and the culture of everyday mathematics, especially in the commercial towns of Italy and the German free imperial cities, have garnered much well-deserved attention recently."[6]

As Smith has noted, "Knowledge moved along with trade: with individuals as they migrated, or were resettled in new territories, and with sailors, soldiers, and merchants as they pursued trade and war."[7] It is with this historiography of collaboration and conversation under which this work will proceed. There were many actors in the concurrent dramas of modern state creation, social development, and oceanic exploration and conquest. My focus will be upon their interactions and dialogue, upon their reciprocal influences, and a broader look at the smaller, less mentioned actors.

Maritime developments and their trajectory should be viewed with the same dispassionate view that a prudent social historian brings to institutional change. The analysis should be objective and not teleological. The trajectory of technology and of institutions is neither preordained, nor is it always accretive, nor is it necessarily salutary. It would be a mistake to view every technological evolution or innovation as an incremental step towards the 'modern ideal.' Therefore, this work will attempt to focus on who, what, where, when, and why. As a great deal of what is now called modern was never achieved through design or intent, our study will not judge the actions of the period by approximating their centrality to achieving the present, but rather upon their temporal and localized efficacy in achieving their sponsor's objectives. However, technological studies tend toward the teleological for reasons which do not hinder the social historian. Societal models and institutions inspire endless debate about their

[6] Smith, Pamela, "Science on the Move," 362.

[7] Ibid, 368, and Dear, Peter, *Revolutionizing the Sciences: European Knowledge and its Ambitions, 1500-1700*, 2nd Edition, 51, "The art of navigation was of especial concern in these centuries of expansion of European trade around the globe, and by the end of the sixteenth century practical navigators had developed much knowledge of how to maneuver ships over enormous distances without getting badly lost."

efficacy, equity, and desirability. It is far harder to debate the advantage of side-mounted steering oars or paddle wheels *vis-à-vis* their pintle-and-gudgeon sternpost rudder or screw propeller competitors. Economic and military competition does not always render the most ideal mechanical solution available, but it does take large social, economic, or resource impediments to halt technological optimization once it has begun.[8] This is especially true when competition is overt and the rewards for qualitative technological advantage are manifest.

We also need to be somewhat circumspect in assessing the reciprocal influence of early modern science and the sea as both our terminology for and concept of both science and its practioners are of very recent origin. Early modern astronomers, cosmographers and natural philosophers, although bearing a loosely analogous relationship to today's scientific community, were not simply earlier versions of our modern and highly specialized researchers and scientists. In most cases, they did not view their work as either above or apart from society or national interest. The modern scientific conceit of dispassionate searchers of objective truth proceeding relentlessly forward immune to either creed or interest cannot easily be cast backward.[9] Indeed,

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[8] Mokyr, 16, contends that technological competition has in the past and in most places, been regularly checked by the stasis induced by societal institutions. "History provides us with relatively few examples of societies that were technologically progressive. Our own world is exceptional, though not unique, in this regard. By and large, the forces opposing technological progress have been stronger than those striving for changes. The study of technological progress is therefore the study of exceptionalism, of cases in which as a result of rare circumstances, the normal tendency of societies to slide toward stasis and equilibrium was broken."

Mokyr, 81, adds that ambition, wedded to maritime prowess had several distinct predecessors, "By 1750, Europe had consolidated its technological superiority over the rest of the world. … Yet, it seems plausible that if European technology had stopped dead in its tracks – as Islam's had by about 1200, China's had by 1450, and Japan's had by 1600 – a global equilibrium would have settled in that would have left the status quo intact, with few exogenous forces to upset it." However, the Ming dynasty and Rome only skirted the edges of the two great oceans, even though the former crossed the Indian Ocean prior to political decisions to halt.

Pomeranz, Kenneth, *The Great Divergence: China, Europe, and the Making of the Modern World Economy*, 55, echoes Mokyr's sentiment on stasis in his comparative study on global technological break-out technological development, "Histories of technology often imagine one breakthrough creating a 'bottleneck' [Thomas P. Hughes' reverse salient] that concentrates efforts on a specific problem and so leads to another breakthrough, as when advances in weaving created incentives to speed up spinning. But such bottlenecks are just as often addressed by allocating more resources, without any change in techniques, and the longer that process of reallocation of resources continues, the less incentive remains to find a technological solution."

[9] Kuhn, Thomas, *The Structure of Scientific Revolutions*, 3rd Edition, 168, notes "one of the strongest, if still unwritten, rules of scientific life is the prohibition of appeals to heads of state or to the populace at large in matters

even our modern idea of science as accretive, progressive, generally salutary, and philosophically neutral has undergone serious revisionist critique over the last half-century.

In the 1960s non-linear development theories evolved within the Philosophy of Science community to analyze and expand this critique and achieve a better understanding of the history of scientific development, together with its societal impact and inputs. One of the early pioneers of this movement developed a novel approach in his seminal book, *The Structure of Scientific Revolutions.*[10] Thomas Kuhn proposed a corrective to the linear and cumulative view of scientific progress that he claims was received wisdom fifty years ago. Kuhn details the unique aspect of the community of natural scientists and their sub-groupings and notes that these communities are built around specific paradigms that not only provide a theory about how nature or some aspect of nature works, but that also provide the rules for investigating nature, for evaluating its results and for providing legitimate avenues for scientific research. Scientists only become scientists when they have become initiated into a specific paradigm and science only becomes 'normal science' when either a dominant paradigm has been created in a previously chaotic and diverse 'immature field' or when a new paradigm replaces an old one.

Kuhn's most famous case study applying his approach, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*, concerns the heliocentric cosmology so central to the later stages of the Age of Exploration and our topic. One does not

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scientific." Kuhn, an ardent challenger of scientific myths appears to have bought one of the largest myths marketed by scientists themselves – that of their superhuman immunity from society – at least regarding their subordination of societal rules *vis-à-vis* those of their dominant theoretical paradigm.

[10] Heilbron, John, "Thomas Samuel Kuhn, 18 July 1922 – 17 June 1996," *Isis*, **89:3** (1998), 505, has noted that, "T.S. Kuhn, physicist, historian, and philosopher, was the most influential analyst of scientific development during the later twentieth century. His enduring book, *The Structure of Scientific Revolutions* (1962), has sold a million copies in two dozen languages. It made 'paradigm shift' as common and misused a metaphor as 'quantum leap' and 'critical mass.' It achieved what few philosophical books have done. It simultaneously instructed a wide academic public and a specialist community."

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have to wholeheartedly embrace his entire philosophy to use some of the analytical tools he provides. Kuhn contends that normal science searches for confirmations of its paradigm, not for Francis Bacon's objective facts or Karl Popper's empirical falsifications. Kuhn in effect is rejecting the Baconian or scientific method as untenable or even as myth. In response to his critics, Kuhn denies the charge that he is a relativist. He claims that this charge is levied because he rejects the teleological view of the march of scientific progress and rather believes in a Darwinian view of science as a march toward no specific goal other than 'best available' temporal adaptation to current circumstance.[11] Throughout our maritime story, we will see this kind of temporal and situational optimization continue as ships, crews, and gun counts all grow, shrink, and grow again. Additionally, Kuhn's refusal to see scientists as dispassionate people set apart from society and its beliefs is a critical aspect of this study that posits the intricate bonds between early modern state-makers, proto-scientists, and the nautical explorers.

In addition, our work is intended to help fill a historiographical content hole. Elaine Leong and Alisha Rankin have compiled some of the new scholarship on the relatively new topic of secrecy in science. In *Secrets and Knowledge in Medicine and Science, 1500-1800,* they note that there are serious omissions in the historical canon regarding secrecy and that "secrets certainly played a key role on other [previously unaddressed] sciences as well: astronomy, cartography, geography and navigation to name a few."[12] In addition to these areas examined in this work, the entire colonial project – impossible without the taming of the oceans – became a two-way conduit between Western Europe and the rest of the world in both the development of

[11] Kuhn, *The Structure of Scientific Revolutions*, 172, although his insight that we should judge a scientific system in the context of the questions it must answer is sound (as in the case of Ptolemaic geocentric astronomy), is his claim that the theories of newer science (i.e. Copernicus's heliocentric astronomy) are simply better suited to answering their own specific puzzles adequate? If newer science does not "approximate more and more closely to, the truth," (206) than how are the facts presented by a paradigm that posits the earth as the center of the universe any different than one in which the earth rotates around the sun? If observations are only to be judged within the context of their own paradigm, how is that anything but relativism?

[12] Leong, Elaine and Alisha Rankin (editors), *Secrets and Knowledge in Medicine and Science, 1500-1800*, 19-20.

scientific knowledge and the growth of state secrecy to safeguard and exploit this knowledge. Of all the facets of the modernizing theme and its maritime nexus explored in this work, none is more prevalent than the repeated interconnectedness of science, secrecy, and the sea. The concluding Literature Review adds more detail to other works and concepts applied herein.

Theory and Method

This work will analyze seven key aspects of modern institutions and society and correlate their evolution with developments at sea. The seven central chapters focus upon:

Chapter 3 – ***The State, Science, and the Sea: The Caravel and the Creation of the Atlantic World – The Portuguese National Research Project***

Chapter 4 – ***Copernican Astronomy and Oceanic Exploration: The Scientific Revolution and the Age of Sail***

Chapter 5 – ***The Rise and Apogee of Spanish Sea Power, Maritime Institutions, and State Secrecy; and Competition from the Protestant North***

Chapter 6 – ***Elizabeth I, Oceans, and the Rise of State Secrecy: The Interconnected Development of Modern Institutions at Sea and at the Seat of Power in Sixteenth Century England***

Chapter 7 – ***English Guns, Science, and Society at Sea: A Study in Technological and Social Compromise from the Armada to the Restoration***

Chapter 8 – ***Dutch Wars and Organized Science: Imitation and Innovation in the Seventeenth and Early Eighteenth Centuries***

Chapter 9 – ***The Royal Navy and the Foundations of the Modern State: Global Wars and Staying Power from the War of Spanish Succession to the Seven Years' War***

The purpose of these chapters is to identify the inspiration, objectives, and thinking behind maritime developments in the metropolis and at sea, and to search for concurrent societal changes. In addition to sifting existing scholarship on both ends of each question (land and sea) to identify conjunctures and influences, we will also look for common actors and conversations. New research will focus upon land-sea connections previously overlooked or trivialized as technical minutiae. The objective is not to force feed a causation narrative, but rather to identify connections and try to identify a Weber-like theme that may permeate the numerous multi-causal aspects of a certain historical or institutional development.

Max Weber explored the origins of modern capitalism in several articles first published in 1904 and 1905. These articles and additional material written by the author eventually became published in book form as *The Protestant Ethic and the Spirit of Capitalism.*[13] Weber understood that highly complex social structures such as modern capitalism did not evolve due to a unitary cause.[14] However, Weber's insight which he explores in his work is that the religious culture of Puritan Protestantism was an indispensable ingredient in producing modern rationalist capitalism. Weber distinguishes this modern capitalism from past economic endeavors by its rational restraint and continuous reinvestment of earnings[15] and by its rational organization and expectations of labor.[16] Weber concludes that the spirit that animated the formation of this newest evolution of capitalism originated with the cold brutally logical world view of Puritan Protestantism (especially in its Calvinist formation). Weber stresses that the residual effect of this religiosity survived in capitalism long after the religious movement which inspired it had faded and that it was this ethos that drove the capitalism of his day.

In this vein, this work will try to ascertain if there was cultural commonality between English *Modernity and the Spirit of the Sea* – piratical, fearless, opportunistic, entrepreneurial, vainglorious, pragmatic, and scientific – and if this spirit permeated both the state makers and

[13] Weber, *The Protestant Ethic and the Spirit of Capitalism*, vii.
[14] Ibid, xvi-xvii, Anthony Giddens in his introduction lists other critical factors in capitalism's Western emergence listed by Weber including (1) the separation of the productive enterprise from the household, (2) the development of the politically autonomous Western city, (3) the tradition of Roman law in its rationalist form, (4) the evolution of the bureaucratic nation-state, (5) the development of double-entry bookkeeping in Renaissance Italy and finally, (6) the series of changes that helped to create a class of free wage-laborers in Western Europe.
[15] Ibid, xxxii.
[16] Ibid, xxxvi. Once again Weber accents the importance of rational bookkeeping in this discussion – pg. xxxv.

sailors of the period and if it was shared and reinforcing.[17] Although acknowledging and referencing the myriad scientific and nautical inputs from across the Mediterranean and Europe, this study will focus upon the English experience from the Tudor dynasty until the Georgian era. Portuguese, Spanish, Dutch, and French experiences will be examined in more detail either when their input was critical for the formation of the English maritime project or for comparative reasons to illustrate the different options tried by policy makers and societies of the period.

Lastly, since militant Protestants were such an active part of the Tudor, Stewart, and Republican maritime communities, we should address the argument positing correlation between their dogma and the early English acceptance of natural science and the celebration of its practitioners.[18] Robert K. Merton's widely read, nuanced, and still debated *Science, Technology and Society in Seventeenth-Century England* proposes this correlation, but it also examines the institutional and societal factors that are most conducive to scientific inquiry and its progress.[19] Our work does not attempt to correlate religion with maritime acumen or the emergence of modern institutions and society, although numerous references are made herein to the religious cast of the different national or regional maritime communities. The specific impact of religious particulars on any of these developments or upon early modern science, if they existed at all, is beyond the scope of this project, other than to note how sectarian loyalties aligned the actors at sea and ashore. However, at the end of Chapter 4 we will examine Merton's observations about the inherent conflicts that existed between science and different social institutions, and at the end

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[17] Yes, the Weber order is reversed, but as our argument conceives reciprocal influences and since *The Age of Sail and the Spirit of Modernity* lacks the poetic punch of the alternative, we chose accordingly.

[18] Shapin, Steven, "Understanding the Merton Thesis," *Isis*, **79:4** (1988), 594-595, notes that Merton never associated Protestant dogma with the *method* of science or the *sanctioning* of its results, although many critics make these specific allegations despite Merton's overt statements to the contrary.

[19] Ibid, 604-605, notes that despite all Merton's "caveats, cautions, and qualifications," the Merton thesis still stirs avid debate "fifty years later … precisely because it has been so widely misrepresented." Without endorsing the thesis, Shapin regrets modern historical timidity whereby historians nuance their arguments into triviality regarding social inputs and historical developments.

of Chapter 6 we will address England's maritime project in light these observations, especially in regard to the secrecy apparatuses erected by the Tudor state to control nautical knowledge.[20] In examining England's maritime evolution and the subsequent changes which developed in its society at large, we will attempt to assess the impacts of these decisions by its policy makers. The myth of open discourse and unfettered research that surrounds early science and the Royal Society must be squared with nautical reality.

Modernity

Modernity and modern are extraordinarily malleable expressions with a varied legacy. Explicit in the words themselves is the concept of division; everything before 'the modern' was starkly different than now. Although social change has been ubiquitous throughout history, the change to the modern was monumental, so much so that entire academic disciplines of philosophy, art theory, social theory, and sociology sprung up to explain and direct the consequences of this revolutionary change in how people ordered their affairs and communities. This sea change in human affairs originated in a specific place over a short number of centuries, but its impact upon the entire world is still enduring.[21]

Anthony Giddens contends that "'Modernity' refers to modes of social life or organization which emerged in Europe from about the seventeenth century onwards and which subsequently became worldwide in their influence."[22] And that "the emergent social order of modernity is *capitalistic* in both its economic system and in its other institutions."[23] This is a

[20] Merton, Robert King, "Science and the Social Order," 328-334, observed that science could not prosper as a ward of the church, the economy, or the state. Despite the wide variety of state structures which supported the early institutionalization of modern science, Merton held that science had a distinct connection to social structures within a state and would function better if embedded within certain social structures rather than others.
[21] Credit must be given to William Shakespeare's *The Tempest*, 1610, for the first usage of 'sea change' to refer to a radical change in the affairs of men; although it works quite well in this context.
[22] Giddens, Anthony, *The Consequences of Modernity*, Introduction, 1.
[23] Ibid, 14.

good place to start. The economic underpinnings of the modern world are visible and well discussed, but the institutions of the modern world are also distinctly different from their traditionalist and local forebears. The *evolution* of these institutions from 'the traditional' to 'the modern' is a subject equally worthy of study.[24] This change was tumultuous and engendered serious critique upon what was becoming a self-evident Western modernizing project.

By the late nineteenth century Europe had experienced dramatic social turmoil as the effects of the Industrial Revolution and global commerce became manifest. Centuries of tradition centered on feudalism, agrarian life, and small medieval town guild practice, which had slowly receded since the 1300s were being quickly replaced by the creation of a large wage labor class and the birth of industrial capitalism. The old social order, no matter how despotic or meager in its ability to produce basic subsistence items, was familiar. In fact it was so familiar, that no one living could remember any other way of life. The new demands of labor specialization and life regulated by the clock rather than by the rhythms of nature brought a myriad of new social problems along with material benefits. Ironically life regulated by the factory clock on land was preceded by centuries of life regulated by the bells and hour-glasses of Europe's sailing vessels (or as Felipe Fernandez-Armesto notes, the lilt of choir boys in Spain's galleons) – life at sea was broken up into watches set at four hour intervals reset each day after a precise reading of solar noon (the apex of the sun's daily transit). The regimented daily modern life so criticized as novel and unnatural was maritime reality throughout the Age of Sail.

This social turmoil helped engender a new school of thought, one dedicated to analyzing and understanding changes in society. Norbert Elias reminds us that "The image of the

[24] Giddens, the author emphasizes 'discontinuities' rather than evolution. In accordance with Marx, Durkheim, and Weber he remarks on the "grand destruction" of traditional ways of life. However, this study will emphasize the multi-causal creation, evolution, and re-tooling of institutions of long lineage from the sixteenth to the eighteenth centuries in conjunction with the maritime projects of the Age of Sail.

individual as an entirely free, independent being, a 'closed personality' who is 'inwardly' quite self-sufficient and separate from all other people, has behind it a long tradition in the development of European societies."[25] This tradition of the transcendental nature of the individual and his/her institutions was challenged vigorously by Emile Durkheim among others.

Durkheim helped create the field of sociology and labored to establish its place among the natural sciences. Durkheim's major insight was to anthropomorphize society. His thoughts were in sharp contrast to the two major schools of thought predominant in late nineteenth century – empiricism (based on experience) and realist. His view was novel – he looked at the social milieu and viewed society as *sui generis*; and it was a living organism.[26] He perceived a symbiotic relationship between the individual and the group: individuals create society, which takes on a collective consciousness of its own. Society then shapes individuals, who later impact societal formation. Durkheim had introduced the concept of the collective. Society was more than just one of many forces that acted on people; its position was central. To Durkheim, "A society is to its members what a god is to the faithful."[27]

Changes in the organization of society have a long lineage. To Karl Marx, history began when people started to "produce their means of subsistence … and their actual material life."[28] From that point, society and its organization could be described solely in terms of the division of labor. Borrowing the structure of Hegel's dialectic to describe a series of historical clashes between social classes, Marx traced the creation of tribal, slave, feudal, and eventually capitalist economies.[29] He was one of the earliest theorists to ascribe the notion of modern to this latest

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[25] Elias, Norbert, *The Civilizing Process*, 202.
[26] Durkheim, Emile, *The Elementary Forms of Religious Life*, 14. "Society is a reality *sui generis*; it has its own characteristics that are either not found in the rest of the universe or are not found there in the same form."
[27] Ibid, 208.
[28] Tucker, *The Marx-Engel Reader*, 150, Marx, "The German Ideology."
[29] Ibid, 151-153, 473, "The history of all hitherto existing society is the history of class struggles." In Marx's theories on social change, economics is the substructure upon which everything rests. Politics, personalities, human

capitalist phase in human development.[30] But Marx did not share the Whig view of history's inexorable march toward progress and social justice. His reading was darker and more critical. He distinctly described the plight of the proletariat worker class under capitalism as a devolving circumstance. [31]

Modernity, often called the offspring of the eighteenth century European Enlightenment, has had critics from its inception. Throughout the birth and rise of the project of modernity, the classical social theorists reacted in dismay to the human impact wrought by its growing pains. Nevertheless, most saw in modernity a path to human elevation and positive social evolution. It would take the tragedy of two world wars, a global economic depression, and the collapse of the global colonial order to fundamentally sever many on the intellectual left from the Western project of modernity. [32] One response, Postmodernism, would challenge the fundamental tenets of modernity, namely the belief in objective knowledge and the ability of the modern project to create a more just society. Social Theory was born amid the turmoil of the modernizing Western industrial world in the middle of the nineteenth century. However, despite wars and dislocations of population centers from rural farms to industrial cities, the overall outlook of the age was

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migrations, climate and geography are just the superstructure of his model. The driving force of society always centers on the means of production and the beneficiaries of the producers' labor. According to Marx, all significant societal change emanates from this historical materialism.

[30] Tucker, 482, Marx and Engels, "Manifesto of the Communist Party." However, Marx stated in 1848 Manifesto of the Communist Party, that all of these "historical movements were movements of minorities, or in the interest of minorities." Only the abolition of all class and property could in Marx's opinion bring about the final and salutary evolution of society – communism.

[31] Ibid, 216, Marx, "Wage Labor and Capital." In his critiques the worker continually trades his/her labor forever decreasing wages as productivity, labor specialization and machination cheapen his/her value. And, Zuckerman, *The Social Theory of W. E. B. DuBois*, 131, DuBois, "Marxism and the Negro Problem." Marx owes this view to his peculiar labor theory of value. In this theory a product's value is not set by the market but "upon the labor necessary to produce them." Marx allowed for cost of materials and machine depreciation, but could not allow for any other morally defensible expense other than those costs coupled with the labor input. Risk, intellectual capital, management acumen, creativity, personal savings, etc. have no value in Marx's calculation – the allocation of "surplus value" to these inputs is little more than "exploitation" of labor by the ruling class.

[32] Lemert, *Social Theory: The Multicultural and Classic Readings*, 193. The two world wars and economic catastrophe shattered this faith and ushered in a more sober and cautious view of society and its rapid changes. According to Lemert, "…in the quarter century between the world wars, from 1919 or so to 1945, the world's events disturbed confidence in the original, uncomplicated version of this faith in Progress." In response, social theorists in the first half of the twentieth century added nuance and depth to the less complicated and hopeful theories of the past.

shaped by a strong belief in the inevitability of technological and social progress. The warnings of notable skeptics like Nietzsche and Weber went unheeded. [33] Charles Lemert contends that enough people of the earlier age shared the fruits of that progress to sustain faith in and pursue programs of progress.

So modernity is destructive and creative; belittling and liberating. It is capitalist, industrial, scientific, and forward looking. Yet, after we clear away all the definition, theory, and critique, we are still left with a marked historical break from a traditional past. The modern period has distinct characteristics and institutions that distinguish it from all historical predecessors. Following Chris Barker,

> "Modernity typically refers to a post-traditional, post-medieval historical period, one marked by the move from feudalism (or agrarianism) toward capitalism, industrialization, secularization, rationalization, the nation-state and its constituent institutions and forms of surveillance."[34]

The modern nation state – centrally organized and secretive; bureaucratically controlled; invested in scientific progress for economic and political aggrandizement; capitalist; technologically dependent and adaptable; and industrial in both economics and war – and its society were in part products and sources of European dominance at sea. In this analysis we will examine the multi-causal creation, evolution, and re-tooling of institutions of long lineage from the beginning of the early modern period through the eighteenth century with these definitions in mind. In particular we will examine the reciprocal linkages between the characteristics and

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[33] Nietzsche, Friedrich, *The Gay Science*, 175. Nietzsche saw the birth of modern individuality as anomalous when viewed in the long context of human existence. He held that, "But during the longest period of the human past nothing was more terrible than to feel that one stood by oneself. To be alone, to experience things by oneself, neither to obey nor to rule, to be an individual – that was not a pleasure but a punishment; one was sentenced 'to individuality.' … In those days, 'free will' was very closely associated with a bad conscience; and the more unfree one's actions were and the more the herd instinct rather than any personal sense found expression in an action, the more moral one felt." The old reality of humans was that of being part of the herd. Modern society and its institutions were just human constructs built by humans to deal with their current perception of reality.

[34] Barker, Chris, *Cultural Studies: Theory and Practice*, 444.

institutions of modern society and the creation and development of the maritime programs of the Atlantic powers, and specifically, those of the English.

Organization and Argument Structure

The overarching structure of this work is chronological, but each chapter focuses on specific aspects of the maritime program and associated characteristics of the modern which invariably spill out of the neat confines of defined periods. For this reason there is some time period overlap between the chapters when essential to complete a point. Each chapter strives to isolate a critical aspect of the modern state and society and the influences that the maritime project may have had on the actors and communities that brought about its development. Like the chronological structure, this too is a bit arbitrary as developments of modern institutions and norms did not solely evolve in the discreet periods assigned, but rather over long periods of time and in many cases centuries. Regardless, for the sake of clarity, the main themes of the modern identified in the thesis are addressed in the most apt period where the most salient developments occurred. Once again, there is spillover of themes between chapters as appropriate, but this is held to a minimum.

Complex stories with high degrees of connectivity to many regions and many past eras require a prologue. The Venetian dominance of the eastern Mediterranean trade routes in the fourteenth and fifteenth centuries cemented more than its economic dominance on the Italian peninsula. This success and the wealth it generated motivated envy in, and intense competition among, the other peninsular trading states. Their repeated frustrations at the hands of Venice prompted some to look westward. If Genoese and Florentine fleets could not dislodge Venice from the Levant, then ducats, nautical expertise, and astronomical knowledge would be put to the service of sponsoring alternative trade routes. Fifteenth century European cosmographic knowledge was itself undergoing rapid transformation, much of it developed to support this internecine Italian seaborne trade war. Competitive maritime trade was helping to propel early humanist scholarship. It is the contention of many that it also provided the early intellectual and financial impetus for the Age of Exploration, starting with the often disparate Iberian Atlantic adventures.

With the Atlantic project's Mediterranean roots acknowledged we will turn to the first great Atlantic forays of the Portuguese and our first glimpse of the emergence of modern mores and associated maritime influence; state sponsored science for national aggrandizement. In this chapter, "The State, Science, and the Sea: The Caravel and the Creation of the Atlantic World – The Portuguese National Research Project," we expand and examine the contention Jan Glete stated in his *Warfare at Sea, 1500-1650*, and apply it to this remarkable effort. Glete note that

> "The growth and transformation of early modern states were usually connected with an interaction process (conflicts, coalitions, compromises) between rulers and subjects about how the resources of the society should be used to organize defense and preparation for war." [35]

In this Atlantic kingdom, the evolution to the early modern started not just with dialogue concerning the allocation of national resources for military endeavors, but rather its commitment of resources to expand existing geographic, hydrographic, astronomical, and navigation knowledge to enhance its trade prospects. In doing so, they transformed the Atlantic from barrier to roadway.

The creation of the Atlantic world with its new connections between four continents and the dawn of what we refer to as the early modern period was made possible by the caravel and the Portuguese state sponsored maritime and scientific program that created her. We will examine this remarkable vessel and the new science that guided her, but as groundbreaking as

[35] Glete, Jan, *Warfare at Sea, 1500-1650: Maritime Conflicts and the Transformation of Europe*, 60.

the caravel was, it, like most past technologies, has been eclipsed by generations of successors. The equally novel state sponsorship of large science based projects however has not receded into memory and is still emblematic of the modern. Fifteenth century Atlantic success led to emulation in Castile and further north, where the most successful maritime programs grew when their patrons emulated the Portuguese by harnessing the resources and will of their emerging states for the development of maritime knowledge.

Therefore, our story about English maritime adventure starts in fifteenth century Atlantic Iberia; a region which was inextricably connected to Italian Renaissance humanists, financiers, and trading conglomerates.[36] However, before we leave Iberia for the Channel, we will focus on a concurrent historical upheaval as significant as the early Atlantic forays; "Copernican Astronomy and Oceanic Exploration: The Scientific Revolution and the Age of Sail." This chapter examines the relationships between the century long development of the 'New Astronomy' (Copernicus' axially rotating and solar orbiting earth, governed by Kepler's laws of planetary motion) of the sixteenth and early seventeenth centuries and the emerging astronomical navigation technologies of the fifteenth and sixteenth century Portuguese, Genoese, and Castilian oceanic explorers and their sixteenth and seventeenth century Protestant competitors. Since the first breakthroughs in Portuguese astronomical navigation in ascertaining latitude at sea were based upon the theories and observations of classically trained Ptolemaic astronomers and cosmographers, it can be argued that the new heliocentric astronomy was not necessary for future developments in early modern navigation. By examining the history of the concurrent revolutions in early modern navigation and astronomy and focusing upon commonalities, we can

[36] The literature supporting this contention is rich and varied. See Felipe Fernandez-Armesto, *Before Columbus: Exploration and Colonization from the Mediterranean to the Atlantic, 1229-1492;* Nicolás Wey Gómez, *The Tropics of Empire: Why Columbus Sailed South to the Indies;* and an excellent symposium on the topic presented in *Fidelio* (Spring 1992), **1:2**.

identify the period during which the old astronomy provided navigators with insufficient results – perhaps hastening the acceptance of the new epistemology championed by Galileo and rejected by Bellarmine. Even though this happened during the period of northern protestant ascendancy in exploration, its roots can be seen during pre-Copernican acceptance in both Lutheran and Catholic Europe. Copernican mathematics was used to calculate Reinhold's Prutenic Tables despite the author's ontological rejection of the heliocentric hypothesis. These tables became essential for ascertaining latitude at sea. Kepler's Rudophine Tables gained even more widespread currency across Europe. His theories were influenced by Gilbert's work on magnetism – a work partially driven by the requirements of English polar exploration. Sailors themselves never needed to accept a heliocentric cosmography, but the data they brought back to the metropolis undermined Ptolemy, and their demand for increased accuracy was incessant as better projected data kept them alive at sea. This exchange between theoretician and user in the early modern period drove both ships and science.

And with this revolution in the methodology for recording and assessing natural knowledge and the state's sponsorship of its acquisition and development, we can observe the early development of other institutions by the state which have evolved into the modern era which had early maritime association. These bureaucratic organizations, with their novel emphasis on restricting maritime knowledge also originated in Iberia. With particular emphasis on Castilian Spain we turn to "The Rise and Apogee of Spanish Sea Power, Maritime Institutions, and State Secrecy; and Competition from the Protestant North."

Portugal and Castile clashed regularly throughout the *Reconquista*, both in Iberia and at sea. They signed several treaties in the late fifteenth century fixing spheres of influence seaward. Although ratified by Pope Alexander VI (the Catalan Rodrigo Borgia), both the Protestant nations of northern Europe and the Catholic monarchs themselves refused to let their colonial aspirations be bound by these treaties. The European discovery of the western hemisphere and of the Indian sea route would inspire centuries of European competition for overseas domination. In this competition nautical information and cosmographical knowledge would become highly prized properties of the state. The knowledge accumulated by the returning Portuguese and Spanish pilots and catalogued by state sponsored cosmographers was heavily regulated and censured and became one of the primary targets of foreign intrigue.

The issue of controlling geographic knowledge in the early modern period with reference to Atlantic cartography and navigational knowledge engendered two conflicting goals facing the Spanish government; specifically its need to both constrain and disseminate this knowledge. Political and diplomatic desires for staking claims clashed with the crown's desire to protect its monopolies and shield its shipping from the state sponsored piracy of its competitors. The Spanish state managed its conflicting objectives through two central state bureaucracies specifically involved in Spain's overseas project. We will examine these thoroughly modern institutions and also the role they played in fostering the development of state security apparatuses in Spain and abroad.

From the onset Portuguese and Spanish seaborne success engendered both admiration and envy northward along the Atlantic seaboard. French, Dutch and English sailors and kings alike wanted to replicate the success of men like da Gama and Cortez. Spanish institutions could try to safeguard their hard earned cosmographic knowledge, but operating their fleets required informed pilots and captains subject to intrigue and abduction. This, combined with Hapsburg control of Spain and their reliance upon their subjects in the Netherlands for cartography and printing, made the dissemination of the new cartographic knowledge all but impossible to prevent. The purloining of navigation secrets and open competition in generating new cosmographic knowledge became a national focus and obsession in the new protestant kingdoms along the English Channel and North Sea. Many local champions advocated a dedication to the sea as a means to grow the wealth, influence, and stature of their nations. As we will observe, few scruples limited this ambition.

England's oceanic aspirations flourished briefly under Henry VII and produced the northern voyages of John Cabot and the discovery of the great cod fisheries off the Newfoundland banks in 1497, but waned considerably in the early sixteenth century as Spain and Portugal respectively built global colonial and trading empires. However, this was not an insignificant period in England's maritime history. We will examine the Dutch and some of their novel maritime inspired institutions which would have such lasting impact on English maritime development. We will examine the early Tudor research programs and observe some of the institution building conducted during the reigns of Henry VIII and his two immediate successors, Edward VI and Mary, which provided the foundation for England's global trade and naval ambitions. We will return with an aged Sebastian Cabot to England and examine the contributions he made to developing English navigation science and the importance of England's new joint-stock venture, the Muscovy Company. We will also note the rapid English maritime advances made possible by Cabot's protégé Stephen Borough and the broadening of the maritime community given access to the fruits of the new navigation science by William Bourne. However, before we leave the Tudors and their institutional changes we will turn to "Elizabeth I, Oceans, and the Rise of State Secrecy: The Interconnected Development of Modern Institutions at Sea and at the Seat of Power in Sixteenth Century England."

The rise of state secrecy apparatuses in Elizabeth I's Tudor England were directly influenced by, and interwoven with, the national oceanic projects of the day. The knowledge first developed and applied in Iberia was a critical focus of England's new institutions, intelligence networks, and secrecy apparatuses. This knowledge also enabled England (along with the Dutch and French) to challenge Hapsburg Spain at sea and across the globe. This chapter examines how England purloined this intellectual and practical knowledge, but more importantly, it compares and contrasts the ways that these states chose to treat these new 'scientific' or 'industrial' secrets. The comparison with Iberia is critical in evaluating the decisions made by policy makers in Tudor England.

With the ascension of Elizabeth I the English aggressively accelerated the oceanic contest with its southern neighbors. It did this at a perilous time in its history, a period in which domestic sectarian rifts and threats of foreign invasion where continuous and ominous. Elizabeth, adverse to both debt and anything but extraordinary taxation, expected the leaders of her Privy Council to cope with these threats without the aid of large standing armies, navies or government bureaucracies. These men would have to both defend England on the cheap and catapult her ambitious and unruly merchant class onto the world's oceans without the benefit of a cutting edge seafaring tradition or an advanced intellectual community versed in the mathematical, astronomical, or cartographic sciences of the day. A primary solution the leaders of the Privy Council chose, to resolve both these dilemmas, concerned the aggressive creation of state espionage and security apparatuses and the judicious use of piracy.

In order to examine this peculiar blend of method to advance the interests of the state, we will focus on four particular servants of this remarkable queen. We will look at a spymaster, a pirate, a mathematician, and a cosmographer. Each of them in their fashion understood or personified the links between sixteenth century power, oceanic prowess, and state secrecy. Sir Francis Walsingham has often been referred to as the creator of the first modern state espionage institution, but he was also an active patron of oceanic exploration, technological acquisition, and English colonialism. Sir Francis Drake was a pirate, an intrepid explorer, an accomplished navigator, a scientific patron, and one of Elizabeth's Vice Admirals against the Armada. William Gilbert was a natural philosopher, the Queen's physician, and a mathematical savant whose work on magnetism both aided the Muscovy Company's polar explorers and deeply influenced Kepler. Lastly, the enigmatic Dr. John Dee, who among many other things, was a cosmographer, an astrologer, a mystic, and a spy. It is the first and last of these characteristics, and the interplay between the two which we will address. It is also the connections between these four archetypes, and between England and her foes from Iberia, and between the national oceanic projects and the rise of state security apparatuses targeting theoretical knowledge, applied science, and oceanic technology, which this chapter hopes to illuminate.

At the end of the sixteenth century the naval forces of Elizabeth and Phillip II meet at sea with the former's ascendance, and we will turn our focus to "English Guns, Science, and Society at Sea: A Study in Technological and Social Compromise from the Armada to the Restoration." Despite the approaching eclipse of Iberian global naval supremacy and its supplanting by the private merchant and pirate fleets of the Dutch Republic and Stewart through Restoration England respectively, the Spanish fleet was avoiding the modernizing impulses of their northern competitors. The aristocratic hierarchy of Hapsburg Spain was dominant and entrenched in its seaborne forces – the gentry commanded the ships, while other highborn individuals the ship's infantry independently. The running of the ship and plotting its course was left to technically competent masters and pilots of lower social status. The Dutch and English through necessity were creating a new social class, the technically competent sea officer. The traditional division between landed aristocrat and lowborn tradesman was disappearing at sea. Both social status and expertise were required in the evolving northern maritime fleets and in this evolution we can glimpse the emergence of the modern manager.

Contemporaneous with the rise of the maritime community and its new sea officers in England we observe the growth in mathematics and applied science dedicated in part to increasing navigational expertise. Initially sponsored by wealthy patrons, we will examine the growth of new colleges and public lectures directed at applied science. The modern epistemology centered on mathematical analysis and precision quantification which developed in this period owes a great deal of its paternity to the English maritime quest. Pioneering in ship design, construction, and maintenance also marked this period with accompanying social upheaval, new administrative structures, and the replacement of craft by managed production. Many of these developments would in part lead to the emergence of the early institutions of modern science which we will review in "Dutch Wars and Organized Science: Imitation and Innovation in the Seventeenth and Early Eighteenth Centuries." But we will first examine Dutch influences on both the English maritime project and upon its new financial institutions.

In the previous chapter we chart the state of the field with regard to ship type evolution in the early modern period from carrack to galleon to race galleon. We will follow this evolution through the seventeenth century Dutch wars by contrasting the now competitive northern Protestant maritime nations. We will note their naval objectives to include the rise and eclipse of armed merchants (Indiamen) and their ultimate reliance on ships of the line and the adoption of the line of battle (LOB) paradigm. Line of battle tactics would dictate European naval warfare from their initial development by Cromwell's sea generals and Admiral Maarten Tromp during the Anglo-Dutch wars of the mid-seventeenth century, for two centuries.[37] But this type of naval warfare was extremely expensive and was most successfully financed in the long-term by the innovative financial institutions pioneered by the Dutch and adapted by the English. These institutions which privileged capital over land heralded not just the rise of capitalism but the social upheaval partially displacing the old aristocracy with new merchant and financial princes. Seventeenth century war at sea and global trade did not create the capitalist system which characterizes our age, but their demands and actors were intimately evolved in its shaping.

These same actors and maritime interests were intimately involved in the creation of new scientific institutions ashore. We will examine the formal birth of English science and its interaction with the sea. To do this we will examine the Royal Society, the Royal Navy, Nature's Book, and Scientific Prizes and maritime exigencies from Gilbert to Halley to Cook. We will also examine Salomon's House and the state; its collision and eventual confluence. The increasingly complex and integrated English maritime community by the end of the seventeenth century embraced merchants, financiers, scientists, academics, ship builders, and a host of other disparate groups focusing their efforts on long-range global maritime trade. The increasingly complex milieu was shaping English society and many of its salient features are recognizable in the modern. Our final case study will specifically focus upon the huge bureaucratic and administrative organization that both promulgated and protected this trade and English values globally. We will examine "The Royal Navy and the Foundations of the Modern State: Global Wars and Staying Power from the War of Spanish Succession to the Seven Years' War."

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[37] Adkins, Roy, *Nelson's Trafalgar: The Battle that Changed the World*, 84. The introduction of complex sailing rigs mixing square and lateen sails, multiple sails per mast, and three large masts, gave naval commanders tactical flexibility only previously available to galley commanders. Larger, purpose built heavy warships replaced dual purpose merchant-armed ships. These heavier ships could both survive heavy artillery fire and deliver devastating damage to opponents using large batteries of uniformly sized cast iron guns on mobile firing trucks that a disciplined crew with a good logistical train could fire repeatedly for hours.

In its eighteenth century wars against France and Spain, England, now Great Britain protected the interests of its increasingly influential maritime community and merchants and adapted its policy to expand and protect global trade. To do this it had to field a navy with global reach and staying power. We will examine how Great Britain accomplished this task and the impact its developments and compromises had on British society as a whole.

We will examine the large complex bureaucracies and intricate logistics network created to sustain the Royal Navy. By the middle of the eighteenth century we will observe an emerging 'naval industrial complex' of technically competent career civil servants, industries devoted to the navy, and the direction of a complex agricultural market which would become emblematic of emerging modernity. Welfare organizations for naval veterans including the naval hospital system, pensions for widows, and the ameliorative projects of the Sick and Hurt Board ashore and at sea were also novel and trend setting and commends scrutiny.

We will leave the shore and assess the social milieu afloat for both officers and seamen. The Royal Navy slowly created the professional sea officer, who we will argue foreshadowed the rise of technically competent and socially respectable middle class management. The professionalization of the Royal Navy's officer corps including its midshipmen training program, its sea competency and time requirements for lieutenants, the requirement to pass examination for promotion, and the captain's seniority lists did not eliminate the impacts of influence and birth, but they certainly laid the groundwork for creating a truly modern meritocracy. Lastly, we will visit the dockyard operations of the Navy Board and assess the idea that they were proto-industrial and presaged the coming tectonic social shift of Britain's Industrial Revolution of the early nineteenth century. As with our previous chapters, we will assess the reciprocal impacts of the maritime project and the emergence of modernity in this island nation.

CHAPTER 2

Ideas and Ducats: The Renaissance and the Atlantic Project

The Global Situation in the 14th and 15th Centuries

The eastern hemispheric land mass at the beginning of the fourteenth century comprised a series of contiguous civilization spheres broadly defined as Indo-Arab, Malay, Chinese, and European. These civilizations interacted, but only where the spheres intersected. These critical intersections, at the Levant and the Strait of Malacca, enabled the internal actors that controlled them to amass great wealth and power. John Francis Guilmartin in his *Galleons and Galleys* presents an excellent summary of the different ‘worlds’ of the fourteenth century and their intersections at the two major ‘choke points’ of the Levant and the Strait of Malacca. He describes Europe as a ‘Peninsula of Peninsulas’ or a geographic feature that encourages seafaring, and divides the European sphere into several sub-spheres: the Atlantic, the Baltic, and the Mediterranean.[1] Although influenced by the Annales School, Guilmartin is not a proponent of geographic determinism as a cursory reading of his peninsula and seafaring juncture might imply. A leading figure in this school and its interpretation of history as something derived from long term social trends heavily shaped by climate and geography was Fernand Braudel.[2] In his seminal work, *The Mediterranean and the Mediterranean World in the Age of Philip II,* he further divides the Mediterranean sub-sphere into western and eastern Mediterranean civilizations. He notes that any historical periods of unity across this divide either quickly deteriorated (e.g. the Roman Empire dividing) or the colonial children on one side of the sea

[1] Guilmartin, *Galleons and Galleys*, 32-33, also discusses a fourth, but declining Viking sub-sphere within the European sphere.
[2] Braudel was editor of the school’s eponymic journal, *Annales d'histoire économique et sociale* from 1956 to 1968.

broke away and became distinct from their parent civilization.[3] In his model, Italy becomes the choke point intersection between the eastern and western spheres. This position is one that Renaissance Venice exploited to its fullest advantage.

The distinguishing characteristic of the age was that no civilization could or would use the oceans to bypass these "choke points" to access the goods, land, or the technology of non-contiguous civilizations. Two notable exceptions to this concern the Genoese Vivaldi bothers and the Ming Admiral Zheng He. John Law in "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," notes that the unsuccessful voyage of Ugolino and Vadino Vivaldi (1291) and their attempt to take a galley around Africa to the Indian Ocean was a direct result of the inadequacy of the Mediterranean galley for coping with long distances, cargo capacity, and surviving the open sea. As Law states

> "The technological object [the Mediterranean oared galley] was dissolved in the face of a stronger adversary, one better able to associate elements than the Italian system builders. … In the struggle between the Atlantic and the galley, the Atlantic was the winner." [4]

The crowded man-powered galley could not carry enough water or supplies to hug a long African desert coast, nor could the long slender craft survive the open Atlantic swells where the winds were more favorable. Felipe Fernández-Armesto in his *Before Columbus: Exploration and Colonization from the Mediterranean to the Atlantic, 1229-1492* notes that this expedition was not an isolated lark, but was the logical product of an intrepid Italian seafaring tradition and that the foray of the Italian republics' galleys along the north Atlantic coast in the late thirteenth

[3] Braudel, Fernand. *The Mediterranean and the Mediterranean World in the Age of Philip II*, Volumes I and II, translated from the French by Sian Reynolds, 134-136, provides the example of the Phoenicians and Carthage, the Greeks and their colonies, Islam and the Maghreb, and Christendom and the Crusader States, for these ruptures.
[4] Law, John, "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," in Bijker, Hughes, and Pinch (editors), *The Social Construction of Technological Systems* 114-117.

century was "almost as bold a venture as the Portuguese swoop out into the south Atlantic 200 years later, in search of westerly trade winds."[5]

On the other side of the Eurasian landmass, the Chinese had more success and a far greater technological system for plying the oceans. However, they did not have a social system capable of sustaining and capitalizing on their advances. The Chinese Admiral Zheng He (Cheng Ho) was sailing from the Chinese sphere to the Indo-Arab sphere in the 1430s, but the Chinese seafaring tradition was obliterated by the political decrees of Ming emperors starting in 1435.[6] This occurred despite the success of Admiral Zheng He's seven voyages (1405-1433) through the Indian Ocean, Arabian Sea, and contact with eastern Africa. Fernández-Armesto acknowledges that

> "The experience of Europe's age of expansion is unique in the history of the world. … Europe's idiosyncrasy seems even more acute when compared with the experience of the Chinese – a people better fitted for a worldwide imperial role, because of their density of population, unity of command and superiority in technology. In the mid-fifteenth century, however, when the Indian Ocean had been explored and the foundations of an overseas empire laid in Java, the Chinese pulled back, perhaps because the decision making elite there was not as dependent on or committed to long-range trade as was that of much of Latin Christendom."[7]

His reasoning may be accurate, or perhaps the Chinese lacked the internal political competition of fractious states and the traditions of independent populations not locked into obedience to a single decision center; indicating that culture matters. Jan Glete, in *Warfare at Sea, 1500-1650: Maritime Conflicts and the Transformation of Europe,* presents a simple materialist explanation. "In fact, the [Zheng He] naval expeditions were very expensive for the Imperial treasury and that

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[5] Fernández-Armesto, Felipe, *Before Columbus: Exploration and Colonization from the Mediterranean to the Atlantic, 1229-1492*, 3. He also echoes Law's assessment about the galley being the wrong vessel for this mission (pg. 152).

[6] Guilmartin, 34, the Ming dynasty's 'Great Withdrawal'.

Glete, 83, notes the comprehensive nature of the withdrawal, in the mid-sixteenth century, "The Chinese emperor had forbidden his subjects to trade with Japan." This provided an opening for the Portuguese to act as middlemen between south China trading Chinese goods to Japan from their entrepôt of Macao starting in 1557.

[7] Fernández-Armesto, *Before Columbus,* 3.

in itself is an explanation for why they ceased."[8] This may be also indicative of the lack of pressing outside motivations (interstate rivalries and existential civilizational competition), a lack of religious fervor, or a lack of national doggedness that were surely present in the Avis monarchy or in Castile, whose early African forays and post-Columbian expeditions were respectively plagued with regular ship losses and very poor returns on investment. Regardless, the Italians and their galleys failed to exploit the oceans, a failure shared by the Ming Chinese. It is also significant to note, that both of these audacious abortive attempts, were primarily coastal expeditions.

So the dilemma remained. In this world of limited connections, Europe's only access to the coveted luxury goods of the East was through the Ottoman controlled Levant. The shipping lanes across the eastern Mediterranean to this trade emporium were controlled by the Italian city states, primarily the Republic of Venice.[9] However, access to, and Muslim control of the Levant were not the only obstacles facing Europeans.

The Europeans of this period were one of the poorer and more stagnant societies in the world.[10] They were just emerging from the Dark Ages, they were concluding centuries of warfare to push Islam out of Iberia, and were recovering from the decimation of over a third of

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[8] Glete, *Warfare at Sea, 1500-1650: Maritime Conflicts and the Transformation of Europe*, 76-77. He contrasts the impact of the far smaller and more successful Portuguese expeditions in the Indian Ocean and notes that, "unlike the Chinese, the Portuguese had ideas of how naval power might be used with profit."

[9] Rush, Tim, "Prince Henry's Navigations," *Fidelio* (Spring 1992), **1:2**, pp. 46, notes that "From the period of Roger Bacon (c.1214-1292) and Ramon Lull (1232-1315), a strategic plan for Christianity to outflank the Venetian-Moslem grip on the eastern Mediterranean, by circumnavigating Africa, or heading west across the Atlantic, was on the table." This plan – of primary concern to the Florentines and Genoese, was grander than Prince Henry's limited African Atlantic trade objective, but it was also impossible to achieve without the knowledge and technology generated by his long diligent program.

[10] Klein, Herbert S., *The Atlantic Slave Trade, 1999, 8th Printing*, 53. Western Europe in the fifteenth century was relatively poor by contemporary world standards – China, India and Asia Minor were all richer.

Pomeranz, *The Great Divergence*, 206, In analyzing the world's leading core regions of the period – the Chinese Yangzi delta, Tokugawa Japan, the Gujarat plain in India, and northwestern Europe – disagrees to a point. Pomeranz asserts that none of these regions *vis à vis* each other was "uniquely productive or economically efficient." However, he notes a discernable advantage outside Europe in agricultural technology, land use (including forest management), and in proto-industries like silk and porcelain production.

their population from the mid-fourteenth century outbreak of the bubonic plague.[11] In addition, late medieval Europe generally did not produce anything that the more advanced societies in Asia or Asia Minor wanted. The only acceptable medium of exchange was precious metals – gold and silver. Specie had been flowing out of Europe for decades at rates exceeding its internal production. As Roger Crowley notes in his *City of Fortune: How Venice Ruled the Seas*,

> "The trade imbalance was huge: Asia had more to sell than the infant industrial base of medieval Europe could offer in return. The Eastern goods had to be paid for with bars of 98 percent pure silver; large reserves of European bullion drained away into the heartlands of Asia."[12]

Herbert Klein in his *The Atlantic Slave Trade* echoes this. Europeans wanted gold from West Africa (slaves, pepper, ivory were all secondary interests). Europeans needed specie to buy Asian luxury goods through the Levant, but there was a "growing scarcity of precious metals in Europe" since Europeans had nothing to trade that Ottomans or Asians wanted.[13] A possible source of additional gold to offset this imbalance was located in Western Africa.[14] However, the camel caravan routes across the Sahara to this gold were controlled by the Muslims of the

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[11] Coclanis, Peter A., "Beyond Atlantic History," in *Atlantic History: a Critical Appraisal*, edited by Jack P. Greene and Philip D. Morgan, 342, uses the Black Death – pandemic of Asian origin 1347 to 1350, to bracket the beginning of early modern period; a period he ends with the Cholera pandemic of 1832, also of Asian (India) origin.

[12] Crowley, Roger, *City of Fortune: How Venice Ruled the Seas*, 161.

[13] Klein, 10. This can be contrasted with Pomeranz's view (pg. 159) of specie as a produced commodity and therefore not indicative of a trade imbalance at all. He extends this logic to analyze the global post-Columbian silver trade to China. Pomeranz, 161, 190, proposes a demand driven model of European transoceanic colonial expansion and trade that centers on fifteenth-century Chinese re-monetization and the resultant voracious demand for American silver – "it was this enormous Chinese demand that allowed Spanish kings to levy heavy mining royalties without pricing most of the New World's silver production out of the market. … Without Asian demand, the mines of the New World would probably have ceased within a few decades to be able to keep earning a profit while paying the rents that kept the Spanish empire functioning."

[14] Russell-Wood, *The Portuguese Empire, 1415-1808: A World on the Move*, xxii, offers an additional reason that Portugal sought out African gold – it was to purchase northern wheat. He notes that "But, for the early period, I did not include among the motivations the need to expand fishing areas and I failed to link the need for gold to the chronic deficit of wheat in Portugal." In this passage we can detect echoes of Braudel – fish and wheat, scarcity and need, driven by demographic and geographic realities, were driving the secular trend ("God and Gold," expansion and search for trade alternatives other than to the Levant were not the only drivers of the Avis program).

Maghreb. Europe wanted a way around this bottleneck and the coast of Africa provided a possible, if not daunting alternative.[15]

In 1415, a farsighted and innovative Portuguese prince involved in the first European crusade from Iberia to Africa saw in the bazaars of conquered Ceuta the potential of sub-Saharan African trade.[16] If Portugal could navigate the African coast, they could procure gold aplenty to finance Europe's eastern trade deficit. Within four decades, the Ottoman sack of Constantinople would create an even greater imperative for sailing south along the African coast. The Turks controlled the Levant and now had access to Black Sea timber resources and a good series of Mediterranean ports.[17] This gave them the ability to build fleets to challenge the Italian republics and deny enemy galley fleets and large trade ships safe wayside ports and supply points. Europe was faced with the possible elimination of eastern trade. Carlo Cipolla in his *Guns, Sails and Empires* addresses the question of how fifteenth century Europe, "weak, isolated

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[15] Guilmartin, 77, notes that hitherto the coast of Africa was only navigable to Europeans in the vicinity of Northwestern Morocco. In fact, the Cape of Bojador (on the West African coast of the Sahara desert at 27 degrees North latitude, southeast of the Canary Islands) was an enormous physical as well as psychological barrier for the coastal trading peoples of the Mediterranean and Iberia. Violent storms, strong currents, treacherous shoals and a lack of protective natural or man-made harbors made its passage to medieval sailors seem impossible. Europeans referred to this part of the ocean as the "Green Sea of Darkness" and thought of it as a place from which sailors did not return. These physical challenges and deep seated reasonably based fears made surmounting this obstacle one of the greatest feats of early Portuguese navigation. Henry the Navigator launched fifteen unsuccessful missions, before one of his captains; Gil Eannes rounded the cape in 1434, opening up the African coast to exploration by Europeans.

[16] Gómez, *The Tropics of Empire*, 296, "The Portuguese empire owed its discovery of the African tropics to Henry the Navigator (1394-1460), the crusading scholar-prince who had distinguished himself in the conquest of the African port of Ceuta. Henry's intense desire to find an anti-Muslim ally in the legendary Prester John of 'the Indies' led Portuguese vessels to the upper banks of the River Gambia (13°28'N). … Indeed, Castile's invention of the tropical domain it called the Indies was predicated on Portugal's invention of the tropical domain of Guinea."

[17] Crowley, *City of Fortune*, 371, The Ottoman sultans "Mehmet and Bayezit had grasped an essential principle of warfare in the closed sea: There was no need for dominion over the waves; it was the land that counted. By working in conjunction with a powerful army and using the fleet for amphibious operations, they had swept up the strategic bases on which galleys, with their need for frequent harbor stops, depended." Crowley chronicles the rise of the Ottomans and their unique strategy of controlling the sea by controlling all the shore around it, but notes that Venice's demise was due to more than just the rise of a larger more energetic rival. He rightly points out that Venice declined due to the interaction of three major trends: (1) Ottoman rudimentary mastery of sea power combined with absolute dominance on land, (2) the ossifying of Venetian social unity exacerbated in his opinion by a widening gap between nobility and the *galeotti* (rowers), and (3) the opening of the Atlantic trade routes enabling the bypassing of the Levant spice trade. The Venetians themselves could impact little more than one of these trends. In the end, geography and Braudel's secular trend, quite possibly made the Venetian demise inevitable.

and besieged," quickly rose to world hegemony and ushered in modernity. [18] With the fall of Constantinople in 1453, a divided Europe was facing a resurgent Islam and the inexorable progress of Ottoman conquest. Cipolla contends that Europeans, particularly those on the North Atlantic coast, rather than unite and contest this existential threat, attacked the seas instead. That this attack resulted in the mastery of the world's oceans and eventually the domination of the land masses joined by them, was due in large part to the propitious marriage of guns and sails. He notes that

> "Exchanging oarsmen for sails and warriors for guns meant essentially the exchanges of human energy for inanimate power. By turning whole-heartedly to the gun-carrying sailing ship the Atlantic peoples broke down the bottleneck inherent in the use of human energy and harnessed, to their advantage, far larger quantities of power. It was then that European sails appeared aggressively on the most distant seas."[19]

Eventually, the Portuguese African mission would evolve into a Iberian-Italian mission focused on discovering a direct ocean route to Asia, but in 1415 Henry the Navigator only needed the dual motives of gold and Christian conversion to drive his maritime program.[20] This

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[18] Cipolla, Carlo M., *Guns, Sails and Empires*, 16.
John Law, "On Methods of Long Distance Control: Vessels, Navigation, and the Portuguese Route to India," 3, poses the question slightly differently: "How was it, in other words, that Christian Europe, at the turn of the fifteenth century, hemmed in in the East by predatory Muslim powers, succeeded so dramatically in turning the tables?"
[19] Cipolla, 81.
[20] Gómez, 295, contends that "Iberia's bid for Africa's side of the Atlantic was itself a natural extension of the arduous southward push of Christian forces through the peninsular territories that had been lost by the Visigoths to Umayyad invaders in 711."

The first Atlantic voyages share a combination of motivations, primarily concerning gold and God. This theme is reiterated in most Atlantic History texts and includes the Spanish, the English and the French as well as Genoese sailors like Christopher Columbus. Behind the simple formulation of gold is always the desire to use it to purchase Asian trade goods. Some examples:

Philips, Carla Rahn, "Europe and the Atlantic," 250, from Greene, Jack P., and Morgan, Philip D., *Atlantic History, A Critical Appraisal*. "Asian dreams" gained appeal after Ottomans seize Constantinople in 1453. The Kingdoms of Portugal and Castile in the late fifteenth century "vied with one another in sponsoring voyages into the 'Ocean Sea'…with Asia as their ultimate goal."

In his monograph, *The Atlantic Slave Trade*, Herbert S. Klein, echoes this same theme, 50.
Once the Portuguese and Spanish opened the Atlantic, the unfolding of events supported the initial motivations in that Europeans still hemorrhaged specie for Asian luxury goods until they started producing tropical consumables in their colonies targeted at a larger consumer class. Some examples:

Canny, Nicholas, "Atlantic and Global History," 325, from Greene, Jack P., and Morgan, Philip D., *Atlantic History, A Critical Appraisal*, (New York; Oxford University Press, 2009). Author notes that Atlantic trade program would both create a remarkable new ship type called the caravel and open the Atlantic and Indian Oceans to Europeans in the next eighty-five years. The caravel, and the long distance oceanic exploitation system it was part of, launched Atlantic Europeans into a rising global ascendancy.[21] Along with this seismic historical development came the accompaniment of official scientific secrecy control in Iberia, with enforcement bureaucracies, and the eventual development of a state security apparatus in Tudor England that was actively interested in the oceanic project in addition to its other concerns. We will also follow the development of bureaucratic and scientific institutions emblematic of the modern that developed in the wake of this maritime expansion. But as the Portuguese launched this project, we must first examine their efforts to develop a new oceanic tradition and also to conceal what they had discovered. However, this focus on the Portuguese necessitates a prologue and a glance further eastward to Renaissance Italy.

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initially just replaces luxury trade with East through Levant in that Europeans were still trading specie for luxury goods, but this time going directly to the source and cutting out the middlemen.

Philips, 262, A large amount of American silver flows to Asian trade by 1560…

Coclanis, 341, The east was the economic motivation of the European merchants. He estimates 75% of American silver ended up in China over the course of the early modern period

Cook, Harold J., "Global Economies …," from Schiebinger, Londa and Swan, Claudia, *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, 101. The early modern is just the "first period of globalization, which linked the silver mines of Peru with the spice trade of Asia and the gun foundries of Europe"

Canizares-Esguerra, Jorges, "How Derivative was Humboldt …," from Schiebinger, Londa and Swan, Claudia, *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, 163. "From Hernan Cortes to [Sir] Walter Raleigh, conquistadors and explorers saw the New World both as an obstacle on the way to Asia and as an endless source of gold and silver."

[21] Law, "On Methods of Long Distance Control: Vessels, Navigation, and the Portuguese Route to India," 2, notes the critical nature of the Columbian landfall and the Portuguese arrival in the Indian Ocean at the close of the fifteenth century as defining moments heralding the rise of Europe to a global dominance lasting five centuries. He acknowledges that extensive study of the period regarding politics, economics, and military strategy rightly exists. However, he notes that the study of the means to European ascension – naval architecture, navigational science and ordnance production – have been left to technical specialists in maritime history. Law sees this as problematic, arguing that "it is not possible to understand this expansion unless the technological, the economic, the political, the social, and the natural are all seen as being interrelated." Law proposes to meld these elements to address the problem the Avis monarchs faced in maintaining "long-distance social control" of their empire.

Renaissance Ideas and Ducats

The Venetian dominance of the eastern Mediterranean trade routes in the fourteenth and fifteenth centuries cemented more than its economic dominance on the Italian peninsula. It motivated envy in and intense competition among the other peninsular trading states. Their repeated frustrations at the hands of Venice prompted some to look westward. If Genoese and Florentine fleets could not dislodge Venice from the Levant, then ducats, nautical expertise, and astronomical knowledge would be put to the service of sponsoring alternative trade routes. Fifteenth century European cosmographic knowledge was itself undergoing rapid transformation, much of it developed to support this internecine Italian seaborne trade war. Nora Hamerman in her review of the religious Council of Florence of 1439 observes that

> "According to the nineteenth-century historian [Gustavo] Uzielli, there was a series of symposia in [Ambrogio] Traversari's monastery on various topics including especially geography, a topic of great interest to the Florentine merchants who wished to break the grip of the Venetian oligarchy on trade with the Orient."[22]

Competitive maritime trade was helping to propel early humanist scholarship. The intense interest in developing ancient knowledge for application to practical maritime problems was greatly accelerated by the first Latin translation in 1406 of Ptolemy's *Geography.*[23]

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[22] Hamerman, Nora, "The Council of Florence: The Religious Event That Shaped the Era of Discovery," *Fidelio* (Spring 1992), **1:2**,, 23-27, notes that the first major split between eastern and western Christianity – the Great Schism 1054 AD – was engendered by the Filioque [Son] principle: belief in Holy Spirit as third person of Trinity, "the necessity of technological progress [of faith] as an indispensable feature of the doctrine of the Trinity …" since the Holy Spirit develops from interaction between the Father and the Son. This theological doctrine threatened the foundation of the autocratic Byzantine patriarchy. This issue was briefly resolved at the Council of Florence. However, far more was produced by the Council then this brief reconciliation which did not survive the fall of Constantinople in 1453. The anti-Aristotelian humanist movement of Francesco Petrarca (Petrarch) and his heirs flourished at Florence. Hamerman notes (26) that "[Ambrogio] Traversari had inherited from Petrarca the task of leading the battle for the Western notion of the Trinity and of liberating Latin learning in the West from the heavy weight of Aristotelianism." Petrarchan humanists fought for the replacement of verbatim translations of ancients with "translate the meaning." [Except Scriptures] For a critical time this allowed for unity between science and religion. She concludes (27) that "It was these circles, fighting for the Filioque, as opposed to the Aristotelians, who launched modern science."

[23] Gómez, 67, "Jacopo d'Angelo's 1406 translation of Ptolemy's *Geography*, the work that established the methods and data of a field we now understand as 'cartography.'"

Original in the John Carter Brown Library at Brown University

Map 2.1. Ptolemy's World: This late fifteenth century European *mappamundi* or 'map of the world' (1482) is based upon the second century A.D. work of Claudius Ptolemy and depicts the Eurasian-African landmass as a linked system with two internal oceans.[24] Knowledge about Africa south of the Sahara was scant; the Levant separated the Mediterranean world from the Middle East and India, which in turn was separated at the Strait of Malacca from Japan, Korea and the Chinese coast. The specifics of Ptolemaic geography were already facing serious scrutiny by Western cosmographers, perhaps as early as the fourteenth century.

After centuries of successful Mediterranean and Black Sea trade, the fourteenth century Italian city states had created enough wealth to sponsor civic, church, and individual scholarship on a level not seen in Christian Europe since the fall of the Latin Roman Empire. Despite the demographic cataclysm of this century and the greater than 50% urban mortality rate wrought by ensuing waves of the Black Death first brought to the western Mediterranean in 1348 by that very same maritime trade from Mongol outposts on the Black Sea, Italy midwifed both the

[24] John Carter Brown Library at Brown University, Brown.edu, https://www.brown.edu/academics/libraries/john-carter-brown/jcb-online/image-collections/map-collection.

Renaissance and the Early Modern Period in Europe.[25] It is the contention of many that it also provided the early intellectual and financial impetus for the Age of Exploration, starting with the often disparate Iberian Atlantic adventure. Fernández-Armesto highlights the determinative nature of Italian involvement in the early Atlantic projects of both major Iberian kingdoms: "The Genoese of Seville played, for Castile in the Atlantic, a role similar to that of the Florentines of Lisbon in the impulsion of Portugal into the Indian Ocean a few years later."[26] Tim Rush cites Italy's most respected Columbus scholar to concur, "the Florentines played an active part in financing and stimulating the Portuguese maritime enterprises."[27]

There were different Atlantic objectives which made up the adventure throughout the emerging Atlantic world. These were pursued by Italian, Catalan, Castilian, and Portuguese with varying degrees of vigor and competition. The great flanking maneuver around Africa to India and the east, the direct westward sail to Cathay, the establishment of Atlantic island plantations in the Azores and Canaries, and even the first attempts at sailing northwest across the Atlantic were all considered possible bonanza scenarios that were pitched by Genoese, Iberian, and Biscayan adventurers to bankers in Florence and Genoa, and to princes from Avis Portugal to Tudor England.

Prince Henry's Portuguese African expeditions and his plantation projects in the Canaries had direct links to Florence. Hamerman observes that

> "In mid-1428, Prince Pedro of Portugal, brother of the famous Henry the Navigator, arrived in Florence to collect maps and pointers for his brother's enterprise. While Portugal contributed the invaluable experience of its seafarers in navigating the deep

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[25] Hamerman, 24, contends that the 12th and 13th century early development of the Western nation state was retarded by "Depopulation [that] had begun at the outset of the fourteenth century, as the impact of the practice of usury and slavery – whether de jure or de facto – struck the poor and defenseless." This major demographic change was exacerbated by the start of recurring ship born bubonic plague events (Black Death) starting in 1348 which killed over 50% of most infected urban population centers.

[26] Fernández -Armesto, *Before Columbus*, 206.

[27] Rush, 50, cites Paolo Emilio Taviani, *Christopher Columbus: The Grand Design*, (London: Orbis, 1985).

> oceans, Florence served as the theoretical storehouse for expeditions into Africa from the Iberian peninsula."[28]

According to Rush, the Portuguese Prince's meetings with "the mathematician [Paolo dal Pozzo] Toscanelli would define the most fruitful of multiple threads of political, economic, and scientific collaboration for the rest of the century."[29] Of critical importance is the reciprocal nature of these relationships. Italian scholars and humanists generated or resurrected theoretical or ancient knowledge, often under the financial patronage of great trading houses, and this knowledge was used, confirmed, corrected, or replaced by the specific discoveries of state sponsored caravel captains and pilots. This feedback loop was critical in resolving classical geographical disagreements between the Aristotelian Ptolemy and followers of Hipparchus such as Strabo.[30] At the Council of Florence the Byzantine scholars had "introduced the Western humanists to the geographical encyclopedia of Strabo."[31] Salvador Lozano contends that both the Italian humanists in Florence, and Prince Henry and Columbus, preferred Strabo to Ptolemy and that their expeditions were in part based upon a "conscious rejection of Ptolemy's geography."[32] The data their expeditions produced would eventually confirm the efficacy of this rejection (at least in regards to Africa, if not regarding the size of the western sea) and lead to the rejection of much of the Aristotelian world view, which in turn aided the humanist movement's ascendancy throughout Europe.

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[28] Hamerman, 28.
[29] Rush, 50.
[30] Lozano, Salvador, "The Battle Against Ptolemy's Geography," *Fidelio* (Spring 1992), **1:2**, pp. 40-43. Translated by Rick Sanders from "The Geography of Exploration and the Fraud of Ptolemy," *Benengeli* (1987), **2:1**. Lozano notes that "The geographic knowledge of Mediterranean civilization had reached a high level just prior to the beginning of the Christian era. … They were well aware that Africa came to an end at a southern cape that was circumnavigable." [contra Ptolemy] And he contends that "some three hundred years after the death of Hipparchus, the fanatical Aristotelian Claudius Ptolemy (90-168 A.D.) became director of the library of the Alexandrian Museum … Ptolemy concocted a series of fables of which the most scandalous was that Africa is not circumnavigable."
[31] Ibid, 41.
[32] Ibid. He adds, 43, "when Bartolomeo Diaz circumnavigated the Cape of Good Hope [1487-88], Christopher Columbus judged the event, and rightly so, as the practical refutation of the Ptolemaic description of the limits of the inhabited world, and a powerful argument in favor of the project in which he played such an outstanding part."

Nicolaus Copernicus, in his *De revolutionibus orbium coelestium (On the Revolutions of the Heavenly Spheres)*, himself notes Ptolemy's great learning and authority, but also his errors,

> "For even if Claud Ptolemy of Alexandia, who stands far in front of all the others on account of his wonderful care and industry, with the help of more than forty years of observations brought this art [astronomy] to such a high point that there seemed to be nothing left which he had not touched upon; nevertheless we see that very many things are not in accord with the movements which should follow from his doctrine but rather with movements which were discovered later and were unkown to him."[33]

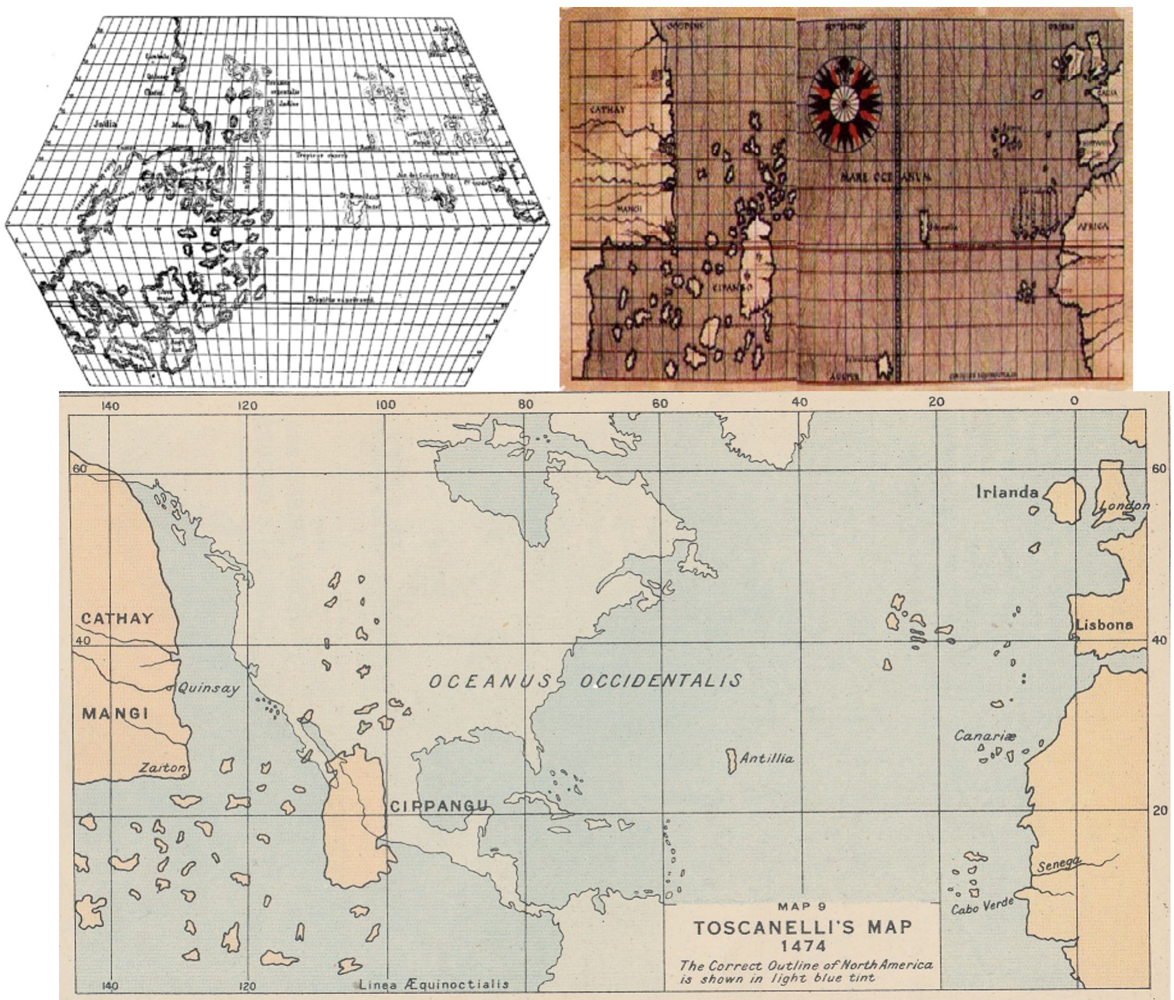
In addition to his remarks concerning Ptolemy's geocentric cosmos, he also notes the problems with his terrestrial geography and latitudinal habitability prohibitions. Atlantic exploration rendered these views obsolete, when "you add to these the islands discovered in our time under the princes of Spain and Portugal and especially America."[34]

Ricardo Olvera notes fifty-three years before the Columbian landfall, the direct transatlantic project had been proposed "In the scientific seminars held during the Council of Florence, [where] Paolo dal Pozzo Toscanelli presented his idea for the project."[35] More significantly, rather than just theorizing in a scholarly vacuum, Toscanelli actively sought out mariners and princes willing to test his theory.

> "The correspondence between … Toscanelli and Christopher Columbus in 1480, and in the ones written by him to Fernão Martins, agent of the Portuguese King Alfonso V, the Florentine scholar urged the Iberian powers – Portugal and Spain – to realize the transatlantic project discussed in Florence, and he laid out for them the map and the scientific information required for its success."[36]

[33] Copernicus, Nicolaus, *On the Revolutions of Heavenly Spheres*, 9 (Book I).
[34] Ibid, 11.
[35] Olvera, Ricardo, "Columbus and Toscanelli," *Fidelio* (Spring 1992), **1:2**, 37. Translated by Rick Sanders from "The Discovery of the Americas and the Great Scientific Project of the Renaissance," *Benengeli* (1987), **2:1**. This in turn was "Based upon the scientific information brought by cosmographers, geographers, and experts in the science of navigation gathered there together."
[36] Ibid.

Columbus' achievement is in no way diminished by this intellectual paternity, he is still the man that turned vision into reality.[37] However, it does illustrate that the Iberian Atlantic project and the direct westward route had Italian influence that reached deeper than its most famous Genoese captain.



Map 2.2. Speculative reconstruction made in 1898 of the map sent by Toscanelli to Fernand Martins, Carte de Toscanelli (1463), and the **Atlantic Ocean according to Paolo dal Pozzo Toscanelli (1474).**[38] The width of the Atlantic is misgauged (the correct outline of North America is shown in blue). Using Lisbon instead of Greenwich as the Prime Meridian shifts this chart a little over 9˚ west, placing Japan and China (*Cippangu* and *Cathay* on the map) about 95 degrees of longitude closer to Europe in a westward voyage than is actually the case. This could only be accomplished by reducing the circumference of the earth, enlarging the width of the Eurasian land mass or a combination of both.

[37] Sanders, Rick, "The Science Behind Columbus," *Fidelio* (Spring 1992), **1:2**, 46, "The science – in the broadest sense of the word – behind Columbus' achievement, was organized before he was born, at the Council of Florence."
[38] Winsor, Justin, "Toscanelli map." *Narrative and Critical History of America*, Volume 2, (1884), https://commons.wikimedia.org/wiki/File:Toscanelli_map.jpg#/media/File:Toscanelli_map.jpg and Wikimedia.org, https://commons.wikimedia.org/wiki/File:Carte_de_Toscanelli.jpg, and Bartholomew, J. G., *A Literary and Historical Atlas of America*, (1911), Edmaps.com, http://www.edmaps.com/Toscanelli_Map_1474.jpg.

The Western Mediterranean and the Fruits of the High Middle Ages

Felipe Fernández-Armesto argues persuasively for the deep seated Mediterranean roots of the newly created Iberian-Italian Atlantic world which predate the Renaissance, Toscanelli, and the Council of Florence. His analysis is both descriptive and comparative. Fernández-Armesto is as concerned with the successful late medieval empire builders – Portugal, Castile, and Genoa – as he is with the conspicuous failures in early Atlantic exploration – both Catalan and French.[39] Fernández-Armesto notes that the Portuguese success in the thirteenth century mirrored their Castilian neighbors in method.[40] These successes in part echoed the thirteenth century Catalan expeditions by the Kingdom of Aragon against Majorca, and its subsequent establishment as the entrepôt of the western Mediterranean. Castile's military success in Andalusia against the Muslims also had salacious results for Genoese traders who built Seville's first maritime links with Africa and the Atlantic. Castile had become a "corridor between the two seas," but Genoa would be the first to profit from this development.[41] Genoa, isolated from its interior by mountains, wedded itself to the sea and grew through piracy aimed at both Christians and Muslims in the western Mediterranean in the 10th and 11th centuries. Crowley notes the maritime advantages exploited by this fiercely individualistic city-state,

> "Genoa was the first to many of the commercial and practical innovations that revolutionized international trade. Gold currency, marine charts [portolan], insurance contracts, the use of the stern rudder, the introduction of public mechanical clocks – the Genoese were using these decades before the Venetians."[42]

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[39] Fernández-Armesto, *Before Columbus*, 5, In fact he is at pains to state that the seaborne imperial projects had theirs roots within the House of Barcelona and that "No explanation of the 'rise' of Portugal or of Castile can be complete without a thorough restrospect[ive] on the frustrations of the Catalans."
[40] Ibid, 64.
[41] Ibid, 12-15, 94. Majorca was also an early and critical center for cartography lead by the Aragonite and Jewish communities (pg. 156).
[42] Crowley, *City of Fortune*, 135 and adds that "the Genoese were marked by a strong streak of individualism and a preference for private enterprise. … the Genoese maritime empire was largely privatized."

Individual and familial concerns amassed wealth and developed their own interests without regard to the benefit of the state. This development stands in stark contrast to the communal capitalism practiced by their Venetian rivals. Adaptable and ambivalent, the Genoese trade 'colonies' relied upon local sovereigns for protection. The Genoese remained focused upon commerce not land, they served their own interests and although they maintained strong Genoese networks, they did not pursue any kind of unified national objectives. From their new base in newly Christianized Andalusia in the late thirteenth century, the Genoese were able to dominate trade with both the Maghreb and establish trade links with northern Europe via the Atlantic. Fernández-Armesto notes that "Andalusia was thus a 'frontier' land of Genoa as well as of Castile."[43]

Genoese trade linked the eastern and western Mediterranean and from Andalusia, and tied both to northern Europe – from the Black Sea to Bruges. Eastern trade stimulated the opening of the first Atlantic shipping routes since the Romans. Mediterranean experiments with island colony agricultural production of luxury items (e.g. sugar) established precedents for the first Atlantic island colonies in the Azores and Canaries. [44] However, Fernández-Armesto contends that the very characteristics that made Catalan and Genoa essential to the early stages of Atlantic exploration (commercial focus, small populations, and adaptive administration) made them unable to sustain an Atlantic presence once their larger Iberian rivals focused their resources toward the Atlantic.[45]

Latin Christendom's focus turned to the Maghreb in the thirteenth century, although their outposts, trade, and limited conquests resembled more of a 'protection racket' than an enduring empire. Fernández-Armesto contends that differing silver-gold valuations drove European trade

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[43] Fernández-Armesto, *Before Columbus*, 112.
[44] Ibid, 198.
[45] Ibid, 119.

arbitrage and eventually exploration for its sub-Saharan source. Although he had just finished tracing the multifaceted origins of the Atlantic project, Fernández-Armesto turns to a clearly economic deterministic rationale for its continuation: "Although Atlantic navigation by Mediterranean mariners had begun earlier and for other reasons, the lure of gold was the decisive stimulus to the new discoveries of the fourteenth and fifteenth centuries."[46]

Fernández-Armesto identifies two overlapping phases of Atlantic expansion. The first phase discussed previously lasted from the late 1200s to the mid fourteenth century and concerned Mediterranean forays northward up the known Atlantic coasts. The second phase spanned the fourteenth and fifteenth centuries (1330s onward) and resulted in the creation and mapping of the hitherto unknown 'Atlantic Mediterranean'.[47] Italian advisors were critical in what were rapidly becoming national projects of both Castile and Portugal.[48] Fernández-Armesto also believes that the major discoveries of the period – the Canaries and the Azores – were accomplished in the fourteenth century with medieval technology. His view is sound, "the true test of a technology is not how sophisticated it is, but how practical it is."[49] But he challenges the need for the advances in fifteenth century astronomical navigation that propelled the caravels southward down the coast of Africa in this phase of Atlantic exploration. Rather Fernández-Armesto contends that the first phase of "exploration of the Atlantic was the fruit of modest miracles of high medieval technology: the cog, the compass, the portolan chart and primitive

[46] Fernández-Armesto, *Before Columbus*, 141-148. Differing gold/silver valuations in North Africa and Europe drive European commerce and island hopping. Maghreb silver-gold valuation was about 10:1; European 13:1 and dropping as trade expanded. European arbitrage – trade aimed at claiming spread.
[47] Ibid, 152, the creation of the 'Atlantic Mediterranean', by Mediterranean mariners – "zone of navigation in previously unexplored waters", from the Azores to north; to the Canaries in the south; to the Iberian and African coasts to east; and linked by the Atlantic wind system.
[48] Ibid, 155.
[49] Ibid, 167

celestial navigation, not with instruments but with the naked eye."[50] This was chiefly a Genoese achievement.

Once discovered, these archipelagoes became the crucible of the Atlantic new world. The Iberian's adapted their medieval mercantile colonial experience from the Mediterranean and Andalusia and applied it to the geographical and environmental conditions of the Atlantic. Labor shortages similar to those in the desolate frontier lands of Reconquista Iberia were endemic and steadily drove the character of the expansion. This became especially true when Prince Henry the Navigator helped create a nascent sugar industry in Madeira.[51] Initially these plantations relied upon immigrant European labor. However, this changed in the 1460s when the Portuguese introduced the slave-based plantation economy model to the newly discovered Cape Verde Islands, which was "unprecedented in European experience since the ancient [Roman] *latifundia*."[52] Once again, this policy had a Genoese architect.

Fernández-Armesto contends that the Iberian maritime empires were shaped by medieval Mediterranean practices, backed by Italian technical and financial assistance, and geographically situated for success. He sees this same combination of cultural-economic-geographic determinism at play in explaining the rise of the Dutch two hundred years later and in explaining 'why not' France or Catalonia. Columbus's watershed journey had deep Mediterranean routes

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50 Fernández-Armesto, *Before Columbus*, 167.

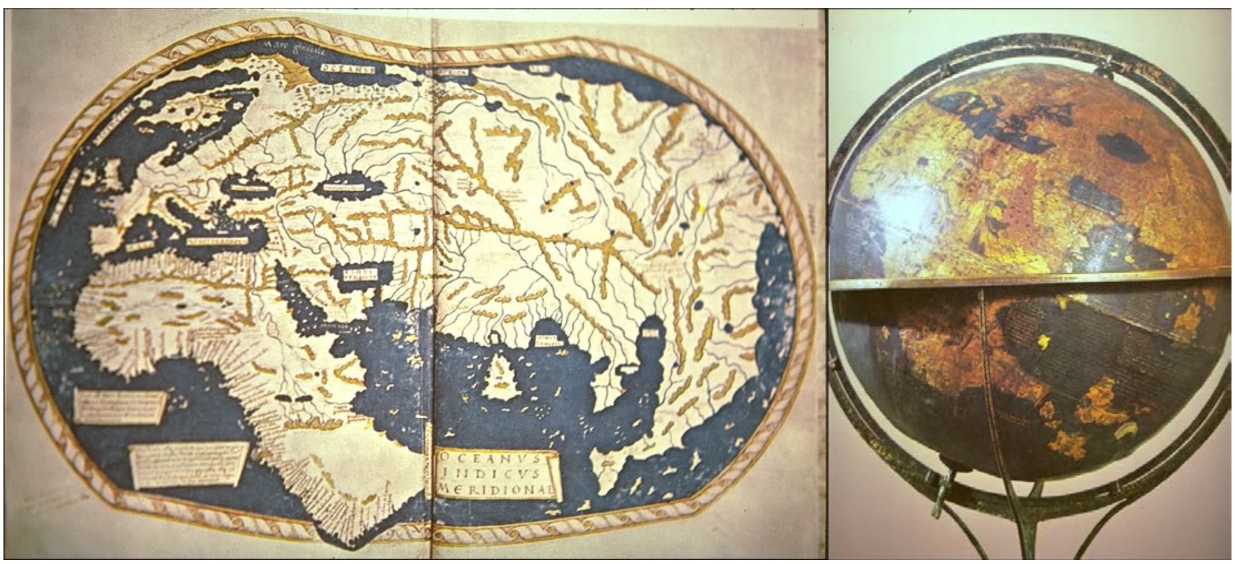
Monmonier, Mark, *Rhumb Lines and Map Wars: A Social History of the Mercator Projection*, 6, notes that "Portolan sailing charts, named after the *portolani* , or pilot books, that guided sailors across the Mediterranean Sea or along the coast of Europe, were distinguished by a network of straight line sailing directions that converge at assorted compass roses." They lacked latitude or longitude lines and covered relatively small global distances.

51 Fernández-Armesto, *Before Columbus*, 198, "Madeira, however, was catapulted into early prosperity by the force of a new product which revolutionized the agronomy in the second half of the fifteenth century: with some of the more westerly of the Canary Islands, it became almost a rival spicerie, supplying sugar, the only Atlantic product that could compete as a high-value condiment with the spices of the east."

52 Ibid, 200-202, "The architect of the settlement of the Cape Verde Islands – and therefore, in a sense, of this new economic model of colonial exploitation which was to become so influential in the New World, was a Genoese, Antonio da Noli." He later switched sides and joined Castile (pg. 204) and became the last 'foreigner' entrusted with crown colonies …

which were both prepared by the Italian humanist revival of the preceding centuries and were ready to be exploited by the evolving Iberian maritime kingdoms that had been incubating in the western Mediterranean and the newly created ‘Atlantic Mediterranean’. Fernández-Armesto makes a convincing case for the Atlantic world’s surviving and visible Mediterranean paternity.

The early modern period in Europe and the Atlantic maritime adventure both had distinct Italian roots. However, where many Renaissance scholars and humanists were looking backward to classical Greece and Rome to relearn what was lost, Atlantic sailors were looking at new horizons. Their near simultaneous emergence would rend the fabric of the medieval world and vastly expand Europe’s provincial gaze. We turn next to Portugal, a small kingdom on the periphery of Western Christendom, where the world started to grow.



Map 2.3. Evolving Fifteenth Century Western Worldview: Henricus Martellus Germanus’ 1490 world map and Martin Behaim’s Nuremberg globe of 1492 both depict the Eurasian-African landmass, but with added African detail provided by the Portuguese forays down the Atlantic coast, an anticipation of a water route around the Cape of Good Hope into the Indian Ocean, and an expectation of a westbound water route across the western ocean to Cathay.[53] The exaggerated width of the Eurasian landmass and the diminished expectation about the earth’s true diameter posited a manageable sailing distance for such a venture.   Both works were also influenced by the Florentine Paolo dal Pozzo Toscanelli’s now lost map and his letter speculating upon a westward sea route to the Spice Islands. His work was in turn heavily influenced by Marco Polo’s *Il milione.* Academic knowledge still was flowing freely in Europe.

[53] “Martellus’ World Maps,” Cartographic-images.net. http://cartographic-images.net/Cartographic_Images/256_Martellus_World_Maps.html and “Behaim Globe,” and Cartographic-images.net, http://cartographic-images.net/Cartographic_Images/258_Behaim_Globe.html

CHAPTER 3.

The State, Science and the Sea: The Caravel and the Creation of the Atlantic World – The Portuguese National Research Project

The Caravel and the Creation of the Atlantic World

On September 28, 1499, Vasco da Gama sailed into Lisbon with only two of the four ships he had left Portugal with over two years earlier. Over half of his original 170 sailors were dead, including his brother Paulo; without enough sailors remaining, da Gama had been forced to burn his brother's leaking *São Rafael* off Malindi, Kenya.[1] But the holds of his surviving vessels were full of pepper, cloves, and cinnamon. Despite his heavy losses and after receiving nothing but "harassment and humiliation" at the hands of the Hindu *zamorin* of Calicut nearly a year earlier, his reception in Lisbon was jubilant.[2] The return of da Gama's battered little fleet constituted the culmination of a nearly century long Portuguese national effort. Under the initial patronage of Prince Henry the Navigator (*Dom Henrique*), the third son of the first Avis king, Joao I, the resources of the Kingdom had poured into this national quest. The emblematic tool of this quest was the caravel, a remarkably seaworthy sailing ship suited to coastal exploration and the wind conditions of the open Atlantic. The navigational and naval knowledge da Gama used to sail his little wooden boats far westward into the Atlantic to travel east, was developed on hundreds of dangerous caravel voyages down the coast of Africa and as far west as Brazil.[3] The

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[1] Owen, Richard, *Great Explorers*, 85. The men were primarily killed by scurvy brought on by lack of vitamin C during their extended time away from shores and fresh rations.

[2] Guilmartin, John Francis, *Galleons and Galleys*, 78-79. When da Gama turned east into the South Atlantic he spent an "unprecedented thirteen weeks out of the sight of land. His fleet consisted of three naos [a vessel very similar to the carrack and often used interchangeably by other authors to describe the larger high walled cargo/war ships of the day], full rigged ships, one of them a supply vessel intended to be emptied and broken up in route, and a caravel, all heavily armed." The Portuguese did not expect to find an advanced civilization in India and brought trade goods that they were used to trading in West Africa. These objects elicited scorn from the local Hindu elite. Despite the combinations of ships used in Portuguese missions of exploration and trade, the core of the Avis system of exploration "from about 1440, was the caravel" (Guilmartin, 77).

[3] Glete, 78, "The final and systematic Portuguese attempt to find a direct maritime route between Europe and India was made in the 1480s and 1490s by the Kings Joao II (r. 1481-1495) and Manual I (r. 1495-1521). The driving

caravel had connected Europe directly to Asia and seven years earlier had taken Columbus to a previously unknown hemisphere.[4] The creation of the Atlantic world with its new connections between four continents and the dawn of what we refer to as the early modern period was made possible by the caravel and the Portuguese naval program that created her.

Figure 3.1. An aged Vasco da Gama, as Viceroy of India and Count of Vidigueira and the Fleet of Vasco da Gama's first Indian Voyage circa 1497. From *Memória das Armadas* (Memorandum of the Fleets)[5] (1) The *São Gabriel*, commanded by Vasco da Gama; a carrack of 178 tons, length approx. 88 feet, width approx. 27'6", draft approx. 7'6"; (2)The *São Rafael*, whose commander was his brother Paulo da Gama; similar dimensions to the São Gabriel; (3) The caravel *Berrio*, slightly smaller than the former two (later re-baptized São Miguel), commanded by Nicolau Coelho; (4) A storage ship of unknown name, commanded by Gonçalo Nunes, later lost near the Bay of São Brás, along the east coast of Africa.

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forces behind the expeditions were to find eastern Christian allies [the Prester John myth] against the Muslims and to create a profitable Portuguese-controlled trade in Asian goods, primarily pepper."

[4] Guilmartin, 87-89, The Portuguese and Columbus used naos to carry supplies for the better sailing caravels. These ships were often destined for disassembly when their stores were expended. On Columbus' first western voyage, his quick and 'weatherly' caravel Nina was a far superior sailor than the 'lubberly' nao Santa Maria.

[5] From the Livro_de_Lisuarte_de_Abreu,
https://en.wikipedia.org/wiki/Vasco_da_Gama#/media/File:Vasco_da_Gama_().jpg.

Albuquerque, Luis de., *Memória das Armadas que de Portugal passaram à Índia,* No. 25, [86] p. : il. Depiction of the first Portuguese India Armada (1497 fleet led by Vasco da Gama) from the *Livro das Armadas* (*Academia de Ciencias de Lisboa*) circa 1568, and Gama_armada_of_1497_(Livro_das_Armadas).jpg.

We will examine a number of questions about this remarkable vessel and her patrons, her creators, and the men who sailed her to *terra incognita*. Our focus will be limited to the following questions. What was the caravel and what made it so special? Why was it developed? What combination of cultural and deterministic factors precipitated its development? What technological innovations did it use? What were the origins of these innovations? Why did the creation of the 'Caravel Culture' occur in fifteenth century Portugal? What was the impact of the caravel on world history?

So what was so special about the caravel? This ship was the quickest and best handling sailing vessel of its time period.[6] It was very seaworthy and weatherly; meaning it was hard to sink and it could sail well in a large number of sea and wind conditions. It was equipped with the most innovative naval technologies of the fifteenth century world. It was built skeleton first (carvel built) with flush joined planking, it had a pintle-and-gudgeon sternpost rudder and boasted one to three masts, usually with lateen sails.[7] The ship was small and had a shallow draft – it could handle the open Atlantic, but could also safely cruise uncharted coastal waters and river estuaries. It could mount one or more of the new cannon just entering maritime service and with its low freeboard could fire devastating volleys *ao lume do agua* (low at the waterline).[8] Despite its small size; its speed, maneuverability and firepower made it formidable against any

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[6] Rush, Tim, "Prince Henry's Navigations," *Fidelio* (Spring 1992), **1:2**, 47, cites Boise Penrose, *Travel and Discovery in the Renaissance*, (Cambridge: Harvard University Press, 1952), "It was thus the combination of hull, size, and rig that made the caravel far and away the most efficient sailing vessel built up to that time. Excellent in windward work, these ships could sail anywhere but into the 'eye of the wind,' while their daily runs in favorable weather sometimes rivalled the logs of the famous clipper ships of a later day."

[7] Guilmartin, 86.

[8] Ibid, 37, 68, 77. In an era dominated by large oared galleys designed to ram, board and fight a floating infantry battle, the ability of this lightly crewed vessel to "hit and run" was critical. These characteristics also enhanced its survivability against Muslim pirates or the sailing vessels of the Atlantic (cogs and carracks), which although large, could not match the caravel for maneuverability. This was an era before the invention of the watertight gun port, so even sailing ships primarily fought by boarding and raining missiles down on deck from large fighting castles fore and aft. With their high free board designed to repel boarders, deck cannon became somewhat ineffective. They shot too high when confronted with the smaller caravel; which shooting along the waterline, could "hull" them and run away for another shot.

opponent it would encounter in the Atlantic or Indian Oceans. We will examine these technologies in due course, but this combination of attributes was unprecedented and unmatched. Tim Rush notes "The development and introduction of the caravel under Henry's sponsorship in the period around 1440, was one of the greatest technological leaps of the Renaissance." [9] The caravel was a ship uniquely designed for exploration in a hostile and unknown world.

So how did Western Europe and Portugal in particular create ground breaking naval technologies, navigation skills, and the cutting edge caravel? Why did not the Chinese or Arabs establish and maintain sustained oceanic technology and trade? Since the fall of Rome and prior to the fourteenth century, global "innovation generally flowed from East to West: algebra, the zero, decimal notation, Arabic numerals [of Indian Hindu paternity], paper, the compass, and gunpowder" are the most celebrated examples.[10] After the beginning of the fourteenth century this flow gradually slowed and then reversed.[11] Regardless, Asia was still more advanced and wealthier than Europe. Even if the transfer of technology was starting a slow directional change, why did these nautical innovations happen in the Atlantic backwaters of Europe? If these breakthroughs were going to happen in Europe at all, then why did not the caravel and its concurrent technologies develop in the more advanced central or eastern Mediterranean? The

[9] Rush, 47,

[10] Guilmartin, 22.

[11] Braudel, 137, expands on this idea of cultural decline and reversal of fortune, "Since the thirteenth century, the East has gradually lost one by one her supremacy in various fields: the refinements of material civilization, technical advance, large industry, banking, and the supply of gold and silver."

This same theme is reiterated by Peter Coclanis in *Atlantic History, A Critical Appraisal*, 340. He delineates the Islamic, Indian, and Chinese knowledge – "paper, printing, measuring devices, equine horse collar, Indic stirrup, gunpowder …, compass and the lateen sail, …number zero" – translated to the West, but acknowledges the creativity required in adapting, applying and improving said technology. He also notes an end to this East-West transfer; "The vast majority of the technologies transferred appeared in the West before the sixteenth century." [His reference to the lateen sail is an error. Iconographic and archeological evidence credits the Romans with developing this technology. The transfer of the lateen sail via the Arabs dates to the sixth century, but goes from the Mediterranean to the Indian Ocean, not the other way around.]

In a similar vein, Greene and Morgan, in the introduction to their 2009 *Atlantic History, A Critical Appraisal* (8), credit the sternpost rudder to the Chinese or the Arabs. Lawrence V. Mott thoroughly debunks this argument with iconographic evidence in his 1997 study of rudders and shipbuilding.

answers to these questions may have a lot to do with fish and the cultural ability to absorb and adapt different technologies.

Let us begin with the fish. We can trace the lineage of the caravel to the medieval European Atlantic fishing boat.[12] But seaworthy fishing boat design does not spring from pastoral, nomadic, or agricultural cultures. Maritime cultures are needed to develop effective sea-going craft. Maritime cultures need two things to develop; proximity to the sea and a reason to risk one's life to travel upon it. The primary reason humans have gone to sea throughout the ages is to fish. But the locations of fisheries (onshore or far out on shallow ocean banks) and the quantities of fish that they can provide have to a large degree determined the amount of resources a society will dedicate to developing maritime technologies and will determine the size and skill of its maritime class and the solutions they devise to access these fish.[13] The caravel originated in the Atlantic fishing cultures, not in the Mediterranean. Why should this have been?

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[12] Despite a number of apocryphal stories about the caravel's origin (such as it being the personal design of Henry the Navigator), there is general consensus among naval historians about this aspect of its parentage. The fishing cultures of the medieval North Atlantic created long haul fishing boats which were used as the basic template for the design of the caravel. See Guilmartin, 77.

Mott, Lawrence V., *The Development of the Rudder A Technological Tale (Studies in Nautical Archaeology, No. 3),* 101-110. He describes the evolution of the medieval Atlantic fishing tradition and the development of their signature trading and naval vessel, the cog. Even though the Romans occupied Britain for 400 years, Scandinavian tradition (shallow draft clinker built single mast boats) and indigenous Celtic maritime traditions supplanted Mediterranean ship building techniques during the Dark Ages. These traditions and the cog were introduced to the Mediterranean world during the Crusades in the twelfth century.

[13] The economic importance of fishing to maritime cultures is hard to overstate. Greene and Morgan, *Atlantic History, A Critical Appraisal*, emphasize the importance of fishing to seafaring cultures by noting the importance of fishing in relation to other human endeavors on the ocean like trade or travel even after the establishment of the Atlantic world. They note that Basque, Norman, Breton, and West Country fishermen were pulling 200,000 metric tons off the Newfoundland Banks annually by 1580, using some 500 ships – trade larger in volume and value than all trade coming from the Gulf of Mexico, 12.

Greene and Morgan see fishing as a topic needing greater understanding. Their third proposition for study of Atlantic History concerns the leading edges of the Atlantic world including fishing and maritime issues. They also state that "Atlantic History does not necessarily have to be explored on both sides of the Atlantic," 12.

A number of authors have noted the late entry of England into the quest for colonies, treasure, and trade routes in the New World and Asia. Joyce Chaplain, notes in her essay on the Atlantic Ocean, 38, that English fishermen were in Iceland in the early 1400s and fishing off Greenland and Newfoundland by the 1470s and 1480s (38). As Trevor Burnard notes in his essay on the British Atlantic in the same volume, the English attention in the sixteenth century was monopolized by the Irish, fish, and "privateering" (112).

Despite popular misconceptions the Mediterranean, with its steep mountainous shores, its drastic offshore underwater topography which plummets rapidly to large depths, and the geological age of its water, has not been blessed with abundant fisheries. In his history of the world of Spain's Phillip II, Fernand Braudel asserts that "the Mediterranean has never been inhabited by the profusion of sea-going peoples found in the northern seas and the Atlantic."[14] In short, too few fish equates to too few fishermen which equates to too few sailors. The caravel would need other lands for its creation and crews.

In contrast, Atlantic and northern Europe boasted some of the world's finest accessible shallow fishing banks in the world. The tuna fisheries off Portugal's southwest Algarve province, the herring fisheries in the Baltic and the large fishing banks of the North Sea and Newfoundland gave rise to extensive seafaring traditions among the Portuguese, Normans, Bretons, Basques, English, Scotts, and Scandinavians.[15] But access to a fishery is not in itself sufficient to create a maritime culture. Fisheries could remain idle due to the lack of technical means of exploitation, or because the economic benefits associated with fishing were outweighed

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[14] Fernand Braudel, in his *The Mediterranean and the Mediterranean World in the Age of Philip II*, takes a very deterministic view of the role geographical and oceanographic factors play in determining the evolution of different societies and their historical fates. He emphasizes that Mediterranean fisheries only produced modest yields, that the sea and its minor seas were deep without shallow shelves and that the water was "geologically too old" and hence, biologically exhausted. He also adds that the only long distance Mediterranean fishing fleet was its coral fleet, 138. Poor soil conditions and poor fish yields could produce a culture that was both agricultural and maritime, such as the Greeks of antiquity, but the shipping they produced was coastal in orientation and their mariner class was small, 144.

Elliot, John H., *Empires of the Atlantic World: Britain and Spain in America, 1492-1830*, 287, notes a similar combination of poor soil and a seafaring history that creates both an agricultural and maritime society in New England.

Crowley, Roger, *Empires of the Sea: The Siege of Malta, the Battle of Lepanto, and the Contest for the Center of the World,* xv, notes "The sea is also barren. The Mediterranean has been formed by dramatic geological collapse, so that the entrancing transparent waters at its edge plunge away sharply into deep submarine gulfs. There are no continental platforms to rival the rich fishing grounds of Newfoundland or the North Sea."

[15] Greene and Morgan, *Atlantic History, A Critical Appraisal*, emphasize the importance of fishing to seafaring cultures by noting the importance of fishing in relation to other human endeavors on the ocean like trade or travel even after the establishment of the Atlantic world. They note that Basque, Norman, Breton and West Country fishermen were pulling 200,000 metric tons off the Newfoundland Banks annually by 1580, using some 500 ships – trade larger in volume and value than all trade coming from the Gulf of Mexico, 12.

Henry the Navigator was awarded the tuna fishing monopoly in the Algarve in 1433.

by the costs of extraction. Also, the transitory nature of an overused natural resource could end a once thriving maritime culture prematurely. Exhaustion of a fishery could mean disaster for a maritime culture, as it did for the Baltic Hanseatic league when the herring stocks declined in the mid-fifteenth century, or it could provide the impetus to find new areas to fish.[16]

Other natural considerations can also guide the development of maritime cultures. In the northern Mediterranean, coastal communities developed in the lee of mountains, which provided their modest vessels protection from the north winds.[17]   Natural harbors and broad river estuaries, like that of the Tagus and the Thames, facilitated the development of seafaring culture. In addition, up until the age of iron ships, expansive sea culture depended on access to large amounts of different timber types.[18] Other resources such as tar, pitch, and cordage from the Baltic would become critical as ocean going vessels increased in size and complexity. Eventually, access to fresh produce, citrus fruits, and tropical medicines such as Peruvian bark (quinine) would become the *sine qua non* of naval stores.[19] However, in the developing stages of a maritime culture, access to wood and sheltered harbors were paramount.

[16] Natkiel, Richard, and Antony Preston, *Atlas of Maritime History*, 34. The Hanseatic League thrived on and then declined with exploitation and exhaustion of Baltic herring stocks by second half of fifteenth century, which resulted in the English and Scottish fishing fleets taking over their market share. The authors do not solely attribute this decline to falling fish yields and recognize that the eclipse of the League had other causes such as the rise of nation states in Northern Europe and the effects of the Baltic War of 1563 to 1570 with Sweden. This conflict and the League's decline are expanded upon in Guilmartin, 98-104 and more thoroughly in Glete, 112-130.

[17] Braudel, 144.

[18] Mott, 133. Author notes particular problems with finding large straight oaks for the steering quarter rudders of large war galleys. Elsewhere, he reviews tree protection programs in Venice and Riviera that were needed to safeguard resource vital to future fleets.

Braudel, 142-143. Author notes the many wood types needed for galley construction and the almost frantic search for fleet timber that even caused trees in Poland to be designated for use in the Spanish Armada. Eventually a timber crisis in the Mediterranean can be tied to lower average ship tonnages of succeeding generations.

We see similar programs in Restoration England regarding forest preservation at home for the shipping industry and naval purposes, and colonial petitions to the Royal Society beseeching help in using its access to the court to harvest North American shipping timber.   ***See Chapter 9.***

[19] Schiebinger, Londa, *Plants and Empire: Colonial Bio-Prospecting in the Atlantic World*, 8, "Mercantilism [or the European colonial project] flourished through the fecund coupling of naval prowess to natural history." By the 18th century sugar is king, "but Peruvian bark [quinine for treating malaria] was the most valuable commodity by weight", notes, 245.

The combination of the availability of existing fisheries, the development of a maritime culture, the blessing of geographic features favorable to navigation, and access to naval timber resources alone could not propel a culture into the ocean for sustained use. These attributes would need to be wedded to the ability to adapt a wide range of technologies to the enormous task of oceanographic exploration. In addition great political will would be needed to pursue this program for long periods of time. A complete synthesis of these features would occur first in Western Europe. Elsewhere in the world, indigenous use of the sea could be minor, such as in West Africa; extensive, but local, as in the Indo-Arab sphere; or extensive and then politically terminated as in Ming China.[20] However, none of this seafaring could be termed 'blue water' or transoceanic. At the dawn of the early modern era, the Atlantic and Pacific Oceans still prevented regular traffic and trade. No nations had caravels or its equivalent sailing the oceans.

The Atlantic maritime cultures from England to Portugal went in search of more fish in the fifteenth century. Iberian Atlantic island exploration and the English rediscovery of the Newfoundland banks, both in the fifteenth century, required the ability to go far from the coast for extended periods of time. Going far out into the ocean was not an easy decision for these

[20] The peoples of Sub-Saharan Western and Central Africa encountered by the Portuguese in the fifteenth century lacked a seafaring tradition. Were the reasons deterministic or cultural, or both? Philip D. Morgan, in his *Africa and the Atlantic* essay in *Atlantic History, A Critical Appraisal*, 223, makes the deterministic case although he leads with a list of missing cultural technologies. He states that no sophisticated boat building techniques, sails or navigation devices, "prevailing winds and currents, lack of sheltered seas, few natural harbors, treacherous offshore bars, and heavy surf limited an indigenous seafaring tradition." Klein, *The Atlantic Slave Trade*, 13, does mention some large coastal canoe trade along river estuaries and for short hops up the coast, but also highlights that most of the islands colonized by Portuguese for trade stations were uninhabited when the Portuguese occupied them, despite being right off African coast. In fact these locations protected the small Portuguese contingents from disease and violence, specifically because of the lack of an indigenous maritime capability.

Guilmartin, 34, The Chinese seafaring tradition was obliterated by the political decrees of Ming emperors in 1435, despite the success of Admiral Cheng Ho's seven voyages (1405-1433) through the Indian Ocean, Arabian Sea and contact with eastern Africa. This decision of China to turn inward heralded centuries of decline and turned the eastern seaboard of China into a wasteland routinely ravished by Japanese pirates. Of China's continental protectorates, only Korea maintained its vibrant fishing culture. This surviving naval tradition helped create Korea's famous Turtle Boats and its hero admiral, Yi Sun-sin, who saved China during Japan's invasions of the late seventeenth century (186-187).

The Amerindian seafaring tradition Columbus encountered in the Caribbean was primarily limited to island hopping canoe and outrigger traffic, but boasted a wide web of circulation throughout the Antilles.

cultures to make. Mediterranean ocean travel of the day was primarily coastal and was conducted in daily rushes from port town to port town.[21] The English had a Scandinavian tradition to draw on when their fishermen headed into the North Atlantic, but the Portuguese did not. In fact, Braudel declares, that even in the time of Prince Henry the Navigator, the Portuguese were still "primarily timid and fearful coast huggers, with no spirit of adventure."[22] In essence, he is calling them Mediterranean sailors. [23] But somehow, through desperation, religious fervor, greed, enlightened leadership, or some combination of the above, the Portuguese set aside this fear, and became Atlantic sailors. And the ship they used was the caravel.

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[21] Braudel, 103-107. Coastal navigation was preeminent until the sixteenth century. The expression of the day was "*costeggiare*" which loosely meant to "avoid the open sea", or to "hug the shore"; transliterates as "to go carefully". Going carefully and travelling along the coast were synonymous in this period. The Mediterranean sailors of the day were technically competent sailors; knowledge and use of the compass ('lodestone') and astrolabe were not uncommon. However, Braudel falls back on a deterministic argument that is hard to refute. In the Mediterranean, you did not ever have to be far from land and navigation by land was eminently more practical than sailing across the open sea. It was more precise, it offered protection from storms and the offshore winds, and it provided mariners with quickly accessible refuge from pirates.

Mott, 98-101, echoes this theme throughout his story of technological development. The Atlantic sailors developed navigational and shipbuilding technologies spurred on by a necessity not faced by the peoples of the more constrained Mediterranean. They also did not have as wide an access to other cultures' technologies being somewhat isolated and being located on the inhospitable colder fringe of the Eurasian land mass.

Fernández-Armesto, 162, challenges received wisdom that Mediterranean mariners were merely coast huggers [Braudel] in the fourteenth century – he does this with a discussion on the Azores (700 miles out) discovery date – he argues for an early discovery date by citing 14th century literary references (if not maps) and a technical argument: (pg. 166) cogs were the main ships of the era used for exploration and they were square rigged. Therefore they could run with the wind, but could not tack (which would require a lateen sail), so the return from the canaries would require using the Atlantic wind system sallying far out north into the western Atlantic (which would inevitably lead to the Azores) in order to find the westerlies to bring one home to Iberia.

[22] Braudel, 108. Author notes in this discourse that after Ceuta and the inglorious naval capabilities displayed by the crusaders in crossing the straits of Gibraltar, that the Portuguese were ready to "tackle the immense problem of navigation on the high seas, in the Atlantic." They were psychologically ready, but they had an enormous amount of ocean going seamanship to master.

[23] Law, "On Methods of Long Distance Control," 6-7, distinguishes between late medieval Mediterranean navigation – pilot book (rutter), magnetic compass, and portolan chart, and North Atlantic navigation – rutter, compass, and lead and line. Atlantic sailors had to face tides, opaque seas (often shallow), and fog. "The vessels [Atlantic cogs and Mediterranean galleys] were physically mobile, forceful and durable only while they stayed *within* the envelope generated by rutters and charts." The Mediterranean galleys were not the only ships unsuited for the open Atlantic, (pg. 3) "The medieval European sailing vessel [the cog] was unable to operate with any degree of safety or certainty beyond European waters. Its range and endurance were limited, its carrying capacity small, its ability to handle adverse weather conditions was restricted and its ability to find its way out of sight of land or soundings was doubtful." This assessment stands in striking contrast to Fernández-Armesto's Azores discovery date conjecture presented in footnote #21.

The caravel was ‘assembled’ at Sagres and the shipyards at Lagos from innovations spanning centuries and from as far away as China. A fusion of North Atlantic technologies developed for fishing boats, cogs, and galleys included a more tapered hull design and the pintle-and-gudgeon sternpost rudder. The rudder was itself a blending of technologies including the wrought iron hinge, the stern mounted rudder and the straight stern post. The sternpost mounted rudder replaced the Scandinavian styled Wythe mounted quarter rudder on cogs in the northern seas in the early twelfth century. Wrought iron metallurgy was becoming available and affordable to municipalities for door hinges on churches and merchants in the eleventh century. Wrought iron had the added benefit of being corrosion resistant when placed in salt water. And from the cog, the vertical or straight stern post was developed.[24] These innovations sailed into the Mediterranean in the twelfth century aboard crusader cogs and influenced local shipwrights.

[24] Mott, 106-110, presents a convincing case for the indigenous northern European origin of this system – the ‘door hinge’ and straight sternpost rudders were unique Northern European developments. Chinese boats did not have stern posts and Arab vessels in the Indian Ocean lashed their rudder to the stern with ropes. The stern location of steering oars can also be found on ancient Egyptian and Roman iconography and artifacts (120-124).

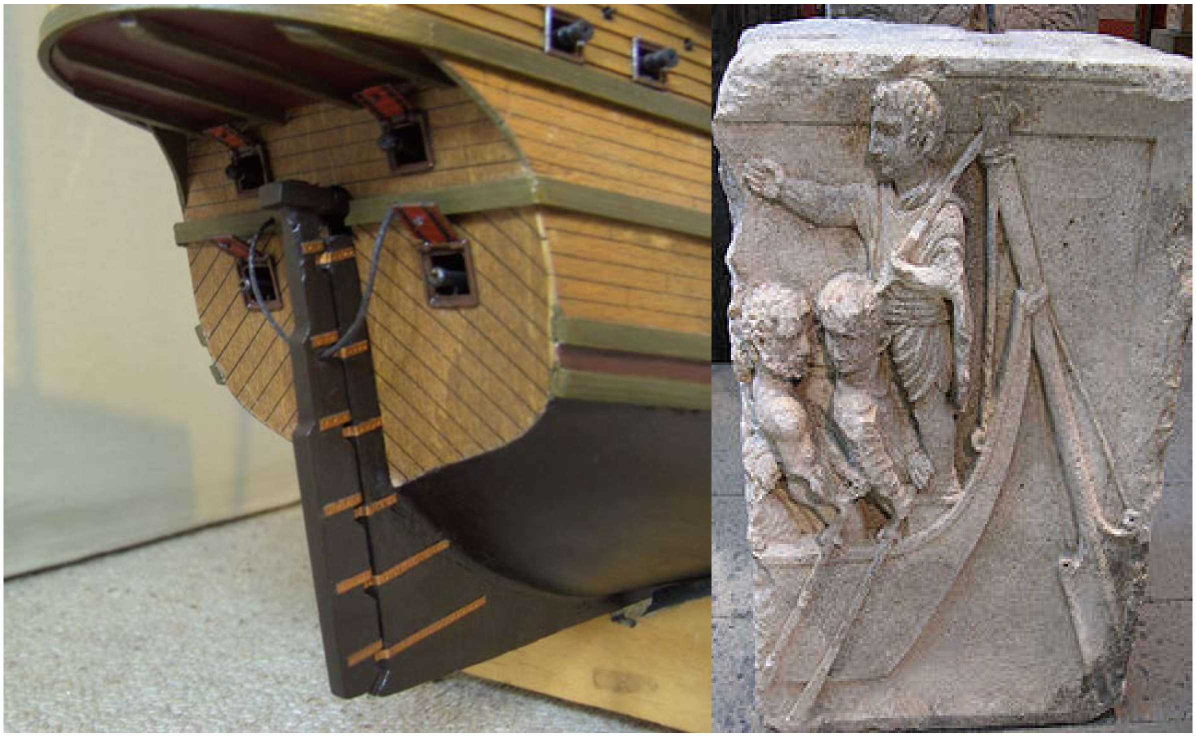

Figure 3.2. The pintle-and-gudgeon sternpost rudder of the Hanseatic league flagship *Adler von Lübeck* (1567–1581), the largest ship in the world at its time, and A **stern mounted steering oar** of a Roman boat, 1st century AD (RG-Museum, Cologne).[25] The great innovation of this rudder system was not the rear mounting, as this had been used intermittently for two millennia as the Roman relief to the right attests, but rather to its "door hinge" mounting to the sternpost using wrought iron. This assembly of innovations – northern ship framing methods allowing a vertical stern post, iron foundry technology, and the rear rudder location – provided the caravel with a durable deep water oceanic steering system that had hitherto never existed.

Mediterranean ships at the time had quarter rudders and tapered aerodynamic sterns. The cog's steering system had advantages for Atlantic waters, but the cog's stern was 'bluff' (rounded, flattened, and broad) which decreased its rudder's effectiveness. The Mediterranean shipwrights, over the course of the next century, redesigned their hulls to taper into a straight stern post adding deadwood to transition the keel to the new stern mounted rudder that they copied from the cog. This innovation blended the strengths of the pintle-and-gudgeon sternpost rudder with the maneuverability of the quarter rudder.[26] Only one more innovation was required to create the premier steering system of the Age of Sail and launch the caravel.

[25] https://upload.wikimedia.org/wikipedia/commons/a/a8/Adler_von_L%C3%BCbeck._Model_ship_05.jpg and an artifact of the Römisch-Germanisches Museum in Köln, Germany.
[26] Mott, 125-135.

Thirteenth century cogs shipped one square mast. Mediterranean vessels shipped multiple masts and took advantage of the sailing strengths of a combination of lateen (Latin-rigged triangular sails hung diagonally along the line of the ship's length) and square rigged sails (hung from yards across the ship's beam or width). The lateen sail is a spectacular example of technology advancing without the impetus of scientific theory or even its recognition. For millennia scattered seafaring communities across the globe have harnessed the almost paradoxical power of using a triangular sail to propel their craft 'close to' (or almost into) the wind. Unlike the more common large square sail hung from a yard on a large mast, whose area is maximized to capture the maximum push that a following wind can give to the sail and therefore the boat, the lateen sail capitalizes on a roughly triangular shape which bulges throughout its course when blown upon. In order to grasp the significance of the lateen sail, it is necessary to detour slightly into the field of aerodynamics. This bulging triangular shape and its angle of attack slightly off the incoming wind create what we now call an airfoil. Operating under the same principal that creates lift under airplane wings, the oncoming wind splits its path across the luff or windward (leading) edge of the triangular sail. The wind travels faster across the longer distance of the bulge in the sail (analogous to the top of the wing). It moves more slowly across the shorter distance of the concave side (or the wing's underside). These speed variances result in lower pressure on the bulge side and create lift (or pressure) on the opposite side. On an airplane wing this lift 'pushes' the wing upward. On a sailing vessel, the lift 'pushes' the sail horizontally as its orientation is roughly perpendicular to the orientation of an airplane wing. Mariners did not need to understand variable wind speeds, resultant pressure pockets, or lift to grasp the significance of this type of sail. Through trial and error, they discovered that by altering the size, shape, and trim of this sail they could increase sail performance and although they still could not sail directly into the wind, they could sail very closely to its point of origin. Over time they also realized that by following a zig-zag course slightly off the wind to the right and then to the left and back again (by rotating or tacking their bow through the wind at the end of each straight run), they could in fact indirectly sail towards the wind. The drawback of the lateen sail was the inverse of its strength. It is not the ideal sail for a following wind and its shape does not maximize that wind's pushing power even when the lateen sail is allowed to rotate well out to the side of the vessel. It was also not a sail suited for the heavy squalls common to the North Atlantic.

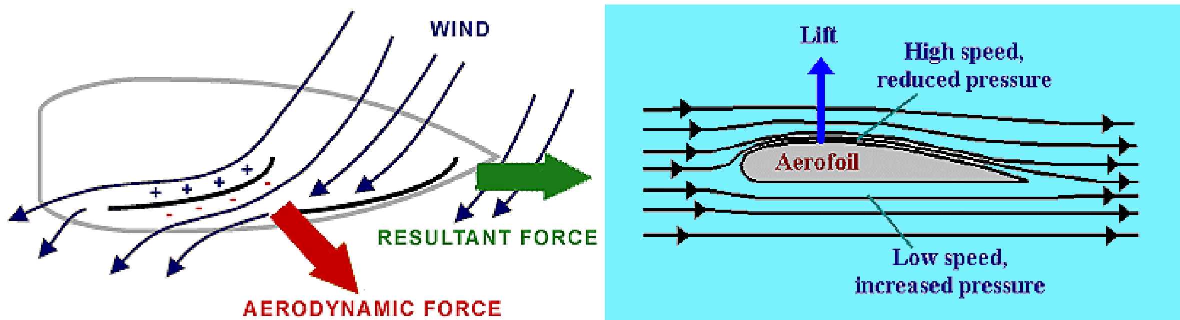

Figure 3.3. Lateen sails: Airfoil without science. The same aerodynamic theory that explains how variable airspeeds over a differentially shaped wing create pressure differentials and uplift on an airplane has been applied in this sailing technology for millennia. Where the aerospace engineer designs his wing utilizing theory and models today to maximize lift, the ancient mariner relied upon trial and error to use his ropes and lines to shape his sail to maximize his speed in a myriad of wind conditions. The insights gleaned provided him freedom from the wind's direction.[27]

The major technological competitor to the lateen sail was the standard square rigged sail. With a following wind or one slightly off to one quarter or the other, this sail could push very large vessels at a respectable speed. However, a single square rigged vessel like the northern cog or the Mediterranean galley was forced to rely on auxiliary power (oars) or risk becoming weather-bound in all but the most favorable circumstances. These problems were compounded when vessels were in port, in dangerous narrow seas, fighting contrary tides and currents, or

[27] "The Sail as an Airfoil – Sailing Upwind," Spinnaker-sailing.com, http://www.spinnaker-sailing.com/lessons/keelboat/k_lessona.htm and "How Sailboats Move - Sailing Theory Airfoil and Hydrofoil," Working-the-sails.com, http://www.working-the-sails.com/how_a_boat_sails.html.

embarking on long voyages through seas with different prevalent wind conditions. The first major solution to this dilemma involved adding masts and combining the major sail types on the same vessel. This amalgam settled into a rather typical pattern of square rig on the main and fore masts, and a lateen sail on the mizzen mast and eventually on the bowsprit.[28] This combination, although not the true ship rig of the age of sail created a far more versatile ship that could harness the power of the wind with large square sails, remain stable in the rough weather of the North Atlantic, and gain maneuverability with its lateen sails. However, the problem of scale remained on vessels constraining masts to single sails.

By 1409, the full rigged ship of three masts with a forward lateen sprit sail had arrived.[29] The process started with the adding of mizzen masts (behind the main mast) in the fourteenth century (circa 1350). By the beginning of the fifteenth century a foremast had been added for balance. A last addition was a lateen sprit sail (also called a jib) for steering placed forward anchored to the foremast and the bowsprit (an angular yard projecting from the bow of the ship).[30] This was not quite the full rigged ship of the Age of Sail with topsails (multiple sails per mast) and numerous staysails or stays'ls (more lateen sails placed well forward and between masts). But the general plan was established.

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[28] Rodger, N.A.M., *The Safeguard of the Sea: A Naval History of Britain*, Vol. 1, *660-1649, 71.*

[29] Rush, 47, notes that "out of Henry's shipyards came an intrinsically revolutionary vessel, with respect to both rigging and hull design. She was three-masted and usually lateen rigged."

Rodger, *Safeguard*, 72, notes "As it developed in in size it came to be rigged with a combination of square and lateen rig of two, three or more masts."

[30] Mott, 142-145.

Braudel, 140, notes the Bay of Biscay origin of the cogs first copied in the Mediterranean and how the combination of multiple masts, with both square and lateen rigs, was applied to them in the subsequent creation of the carrack. He notes that by 1485, that the carrack became the dominant sailing vessel in both the Mediterranean and the Atlantic.

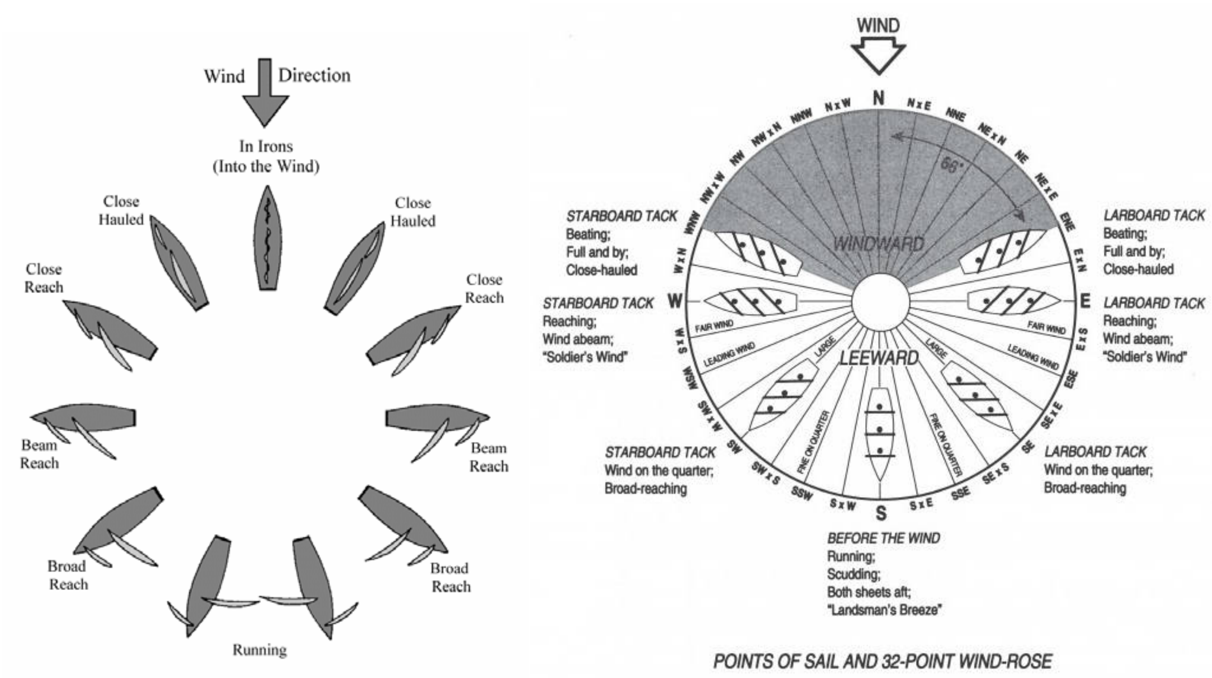

Figure 3.4. Points of sail today and in the Age of Sail.[31] The modern sailboat can sail very close to the wind and generates excellent speed both close hauled and in a close reach. It can run with the wind, but usually deploys spinnakers to counter the inefficiencies of these points of sail. The mixture of the lateen and square rig allowed the vessels of the Age of Sail to head up within 6-points of the wind. The Tudor compass rose (see Chapter 7) was divided into 32 points; each was 11-1/4˚. Although not nearly as maneuverable as today's sailing boats, by tacking and 'beating to windward' these ships could zig-zag their way in almost any wind condition.

In the fourteenth and fifteenth centuries the large main sail and its yard was hauled by manpower and primitive windlasses into place. Ship size could increase with a larger main mast and a bigger sail, but the ship and manning its sail would require an ever increasingly large crew. Adding new masts provided some increased maneuverability since the crew could unbalance the rig by adding sail to the foremast or mizzen as required. N.A.M. Rodger notes that more mundane technical adaptations like adding man-ropes on permanent yards, subdividing the sails on each mast (between course and topsail), and dividing masts into pieces increased ship responsiveness when maneuvering or reacting to wind changes, and most significantly required

[31] "Points of Sail," Knotalotsailing.wordpress.com, https://knotalotsailing.wordpress.com/sailing-101/points-of-sail/ and "Points of Sail and the Compass Rose," Historicnavalfiction.com. https://www.historicnavalfiction.com/general-hnf-info/naval-facts/points-of-sail-and-the-compass-rose.

far less manpower.[32] Using assembled components rather than single large parts also increased the ability to upsize ships while at the same time, decrease construction costs. Rodger notes that "The limitations of the old single-masted rig were broken in the space of little more than a generation by the development in the fifteenth century of the three-masted square rig, the ancestor of the modern 'ship' rig."[33] When combined, all these advances assured the ascendancy of the sailing ship in both trade and warfare over its rival, the galley. By creating an adaptable rig system, including different sail types, fifteenth century sailors set in motion changes, that when they reached their pinnacle in the ship-rigged sailing vessel of the sixteenth century, negated the large advantages galley's possessed regarding wind flexibility and maneuverability, while still maintaining the advantages in seaworthiness, carrying capacity, and fractional manpower requirements that sailing vessels had always possessed. Ingenuity had not just harnessed wind power, but had made it adaptable.

This new early ship rigging, combined with the tapered keel hull and the pintle-and-gudgeon sternpost rudder created the most maneuverable ships in the world. The new ship design could now boast running speed (no rudder or stern drag), stability (provided by the tapered keel) and fine maneuverability (provided by the combination of sails and the rudder). The caravel's hull itself was shaped like an Atlantic fishing boat, but the carvel construction technique was a Mediterranean innovation. The cog had a length to beam (width) ratio of 2:1. The caravel resembled its fishing parent and had a ratio as high as 4:1.[34] The hull was now

[32] Rodger, *Safeguard*, 72.
[33] Ibid, 71.
Lane, Frederic C., *Venetian Ships and Shipbuilders of the Renaissance*, 42, notes that "the coming displacement of the single deep-bellied mainsail by many smaller square sails hung on as many yards on the same mast [produced] a change that would make the canvas stand flatter, the mast look higher, and the ship stand nearer the wind." He adds, 45, that this rapid progress preceded oceanic exploration.
[34] Rush, 47.

carvel built skeleton first with flush joined planking, but the real benefit of the skeleton framing technique was the flexibility it provided shipwrights in buttressing the hull when they started adding a new innovation – naval cannon.[35] For the caravel to be effective in its role, it had to do more than just go to strange new seas and return. It had to survive and often impose its will while on station. Surviving meant exploiting gunpowder.

Gunpowder probably came to Europe from China with the Mongols in the thirteenth century. However, its enormous impact on warfare would not be realized until Europeans refined it and married it to advanced metallurgy and foundry technology. European experimentation with gunpowder component mixing, transformed it from a showy "pyrotechnic to power."[36] Europeans also developed critical wrought iron, bronze casting, and eventually iron casting techniques in their smiths and foundries that enabled them to safely harness the explosive power of the more capable powder they were creating. But these innovations were primarily for land based canon. The big breakthrough for naval design came when European chemists overcame the problem of mixing saltwater and gunpowder.

The earliest gunpowder was deliquescent; it readily absorbed moisture and dissolved, and therefore was an ineffective naval missile propellant. At the beginning of the fifteenth century, Europeans overcame this obstacle by treating aqueous saltpeter with wood ash and created

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Guilmartin, 86, claims that the ratio was even higher at 5:1. The India caravels could be 80-130 tons displacement and sport three to four masts, but had poor cargo capacity and lacked the sailing ability of the newer *naos* or carracks (destined to evolve into the full rigged ship).

[35] Rodger, *Safeguard*, 62-63, notes that "carvel building was considerably more economical in timber and shipbuilding skills." It capitalized upon sawn planks – made possible by water powered saw mills – rather than cloveboard. It utilized nails rather than rivets as did the clinker-built tradition, reducing costly iron consumption.

[36] Guilmartin, 22, 60-62. Gunpowder, a combination of salt peter, charcoal and sulfur, can be created with any number of mixes or recipes. Europeans throughout the thirteenth and fourteenth centuries experimented with different mixes and arrived at optimum blends that could be consistently produced. These blends and their effects could be empirically observed and noted. The big breakthrough came with a new method of mixing, baking, and drying out recently created gunpowder. This technique was called 'corned' powder – it was consistent, powerful, and measureable. With this consistency, the study of ballistics, flight trajectories, and physics could begin. Gunnery had started to evolve as a science.

maritime gunpowder.[37] By 1410, large wrought iron guns (bombards) were appearing on galleys and other shipping in the Mediterranean. Naval warfare was entering a period of dramatic change. Millennia of boarding and ramming tactics would give way to the scientific methods of maneuver and firepower and the caravel was at the cutting edge of this revolution.

Figure 3.5. *La Niña* (replica of the *Santa Clara*) – one of the two caravels Columbus had on his 1492 voyage.[38] Note the mixed rig of square and lateen sails to harness most wind conditions, the tapered long length to beam ratio of the hull and the pintle-and-gudgeon sternpost rudder. *La Pinta* the second of Columbus' caravels is only remembered to history by its nickname. The *Santa María*, the largest of his three ships was a carrack (or nao).

By 1440 the Portuguese had in the caravel a technological marvel they could use to gather and assimilate navigational, oceanographic, and geographical data. The ship could go into

[37] Rodger, *Safeguard*, 209, corned powder replaced serpentine powder which was a chemical mixture – not a compound – therefore it separated in storage, and its saltpeter was hydroscopic and decayed when moist. "Corned powder underwent an additional stage of manufacturing by which small lumps or 'corns' of powder were glazed."

Guilmartin, 60, notes that by treating aqueous saltpeter with wood ash the Europeans replaced the original Chinese calcium nitrate component ($CaNO_3$) with potassium nitrate (KNO_3) thus creating a dry powder that would not absorb water from the moist sea air and spoil. The old hydroscopic powder of Chinese origin had to be kept away from the open air and was relatively useless for naval combat.

[38] Winner, Don, "A Replica Of "La Niña" To Visit Panama," Panama-guide.com, http://www.panama-guide.com/article.php/20090212123730796.

almost any sea or shore condition. It was quick, maneuverable, and able to survive most any conflict it was liable to encounter. But the Portuguese needed another key component in order to make their program successful. They needed to know where they had been and needed a method to reliably guide their return.

Ironically at the pinnacle of its success, the caravel was already in eclipse. The innovative nautical revolution that created her was progressing unabated. With the development of the watertight gunport, larger, heavier gunned ships would soon become the platforms for future development.[39] The caravel was built for exploration, not trade. It could no longer grow in size without losing the sailing qualities that made her so valuable. Additionally, its success as a warship was soon diminished by larger carracks and galleons carrying many more guns on the waterline, fired through the new gunport. Adding to the irony is that it was the adoption of carvel-built hull construction that made the gunport possible. Angus Konstam notes that port holes were easier to structurally accommodate on frame construction, "While this did not propose a problem for carvel-built ships, piercing the side of a clinker-built hull seriously weakened the ship."[40] Gunports in structurally capable hulls enabled both up-gunning and increased ship size. Sustained long-distance trade and control required a larger, cargo carrying, and more survivable ship. The caravel was not this ship.

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[39] Guilmartin, 86-98, caravels were smaller, faster and originally sailed better than the larger carracks and naos. However the development of watertight gunports and full ship-rigging overcame these advantages.

Konstam, Angus, *Sovereigns of the Sea: The Quest to Build the Perfect Renaissance Battleship,* 43, "Gun ports, a relatively new invention, allowed guns to be carried lower in the hull, an improvement over a mere aperture in the hull in that the hole itself could be sealed by a gun port lid. Like many relatively simple technical developments, it opened up a whole range of possibilities. In theory gun ports would make vessels less top-heavy." He adds, 121, "French legend [contends] that gun ports were first invented during the first decade of the sixteenth century by a French shipwright called Descharges of Brest, then chances are that the *Michael* [James IV's Scottish battleship of 1512] was one of the first ships to take advantage of this invention."

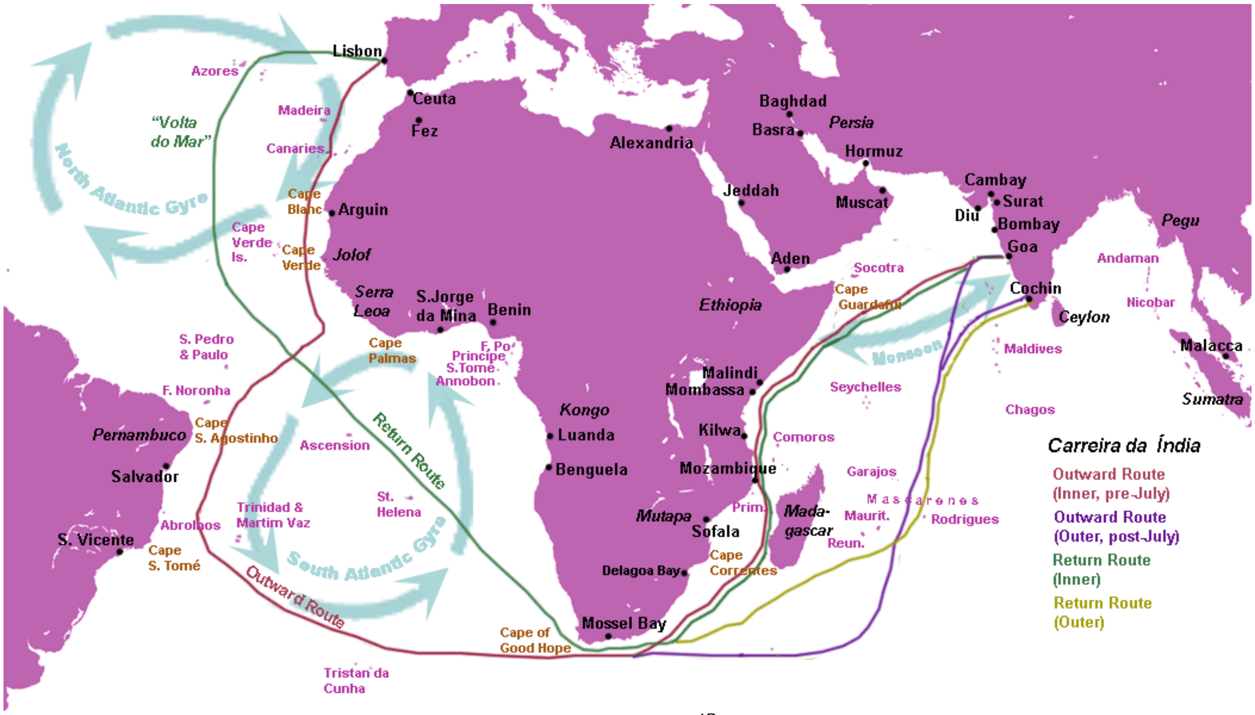
[40] Ibid, 40, he elaborates, 26, "The ship drew its strength from the way the outer hull was fastened together, rather than from a series of rigid internal frames." The northern clinker-built hull strength was contingent upon continuity and lack of weak points along entire hull (gunports) and its hull as a single structure limited its size and carrying capacity.

Let us again return to Vasco da Gama. His object was to bypass the Ottoman Levant and find an ocean rout to the Indies.[41] What he accomplished was to pioneer a route to the Indies that could be safely repeated again and again. As Tim Rush has noted, Da Gama's route eastward with its long westward tack south of the equator almost to Brazil,

> "Was a route that was not to be improved upon in the next four hundred years … it involved being out of sight of land for over three months and 3,800 miles (compared to Columbus' thirty-three days and 2,000 miles), it cut the time of the passage in half. It was a staggering feat of seamanship."[42]

Once he achieved this objective, one pioneered by Prince Henry eighty years earlier and made possible by the subsequent voyages of hundreds of intrepid caravel crews, Portugal was triumphant. Venice's eastern spice monopoly was broken, and when combined with Columbus' Caribbean discoveries earlier in the decade, European expansion was about to begin. The caravel had opened the door to the early modern era by incorporating centuries of world-wide inputs, which in turn created a world changing vehicle. Because of the caravel, for better or for worse, Europe, the Americas, Africa, and Asia would be forever connected by ocean highways. However, the caravel, however novel and important, was just a tool in the much grander Portuguese state sponsored Atlantic project.

[41] Crowley, *City of Fortune*, 372-373, notes that Portuguese control of Moluccas made possible by their Atlantic caravel forays eventually becomes the "hand on the throat of the Venetians"
[42] Rush, 48.



Map 3.1. Da Gama's pioneering voyage to India of 1498-99. [43] The Portuguese caravel program after years of arduous success in creeping down the western coast of Africa was almost abandoned with the discovery of the long eastern taper of the Benin coast. The solution entailed using the South atlantic Gyre and sailing westward to go eastward south of the equator and trusting one's ship for thousands of miles at sea without any sight of land in the often elusive search for the trade winds of the lower forties. The two hemispheric gyres are depicted here, as is the earlier Portuguese discovery of the Volta do Mar or 'return from the sea' which made the earlier voyages in the northern hemisphere possible.

The 15th Century Portuguese Nautical Research Program

Under the initial leadership of Prince Henry and continued by the Avis kings, the Portuguese displayed an unwavering commitment to their oceanic goals. In order to achieve these goals, they would need to refine their chosen tool (the caravel) and expand their nautical knowledge. Henry established the world's first known school of navigation at Sagres, on the southwest extremity of Europe shortly after returning from Ceuta.[44] He established what would

[43] "Portuguese India Armadas," Wikipedia.org, https://en.wikipedia.org/wiki/Portuguese_India_Armadas#/media/File:Map_of_Portuguese_Carreira_da_India.gif.

[44] Natkiel and Preston, 40. The actual school at Sagres is possibly apocryphal – there are no early records of its formal existence and it is first mentioned in a seventeenth century English book. However, its possible destruction in the Lisbon earthquake of 1755 and the subsequent destruction of many early Avis records in the ensuing fires, provide a credible explanation for the lack of contemporaneous documentary evidence.

develop over the fifteenth century into what Guilmartin has described as the Avis oceanic exploration and trade program,

> "By the last quarter of the fifteenth century, the Portuguese had developed a coherent system of deep-sea navigation aimed at commercial profit and underwritten by armed violence. It was based on experimentally derived knowledge of solar and stellar navigation; superior nautical charts; ships that could reliably transverse the broad reaches of the Atlantic and serve as effective gun platforms; and steadily expanding geographical knowledge, not least the wind patterns and currents of the southern Atlantic."[45]

The tools the Portuguese used to feed empirical data into this program were the caravel and metropolis trained pilots.[46] By 1440 the Portuguese had refined the caravel and were accumulating oceanographic, geographical, and meteorological in the Atlantic Ocean.[47] By 1434, Henry's sailors had reached the Azores and after fifteen failed expeditions Gil Eanes had rounded the dreaded Saharan Cape of Bojador (southeast of the Canary Islands).[48] Crossing this huge physical and psychological barrier opened up the entire west coast of Africa to future Portuguese exploration, trade, and the establishment of factories (armed island storehouses). By 1487 Bartholomew Diaz had rounded the Cape of Good Hope. If the caravel was the space shuttle of its age, then Sagres was Cape Canaveral. As Tim Rush has observed

> "Sagres became the intersection point for all facets of Henry's project: his intelligence-gathering machine; the training of the personnel for the voyages within his household; the revolutionary advances in ship design centering on the caravel, carried out at the Lagos shipyards built and supervised by Henry; the design and execution of a colonization policy; all intermixed with a core group of resident cartographers, scientists, and geographers, and a stream of visitors from throughout the known world."[49]

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[45] Guilmartin, 77.
[46] Sandman, Alison and Eric Ash, "Trading Expertise: Sebastian Cabot between Spain and England." *Renaissance Quarterly*, **57** (2004), 818, 837-838, note that these pilots were themselves experienced seamen in the tradition of chart and bearing sailing, tide and current recognition, and shipboard management. The training from the metropolis primarily concerned celestial navigation and using cosmographer crafted instruments and prepared astronomical tables to ascertain latitude at sea.
[47] Braudel, 108. "However, once the caravels had been perfected – the revolutionary ships developed in 1439-1440 to meet the difficulties encountered on the return voyage from Guinea of a head wind and contrary currents – they had to take to the open sea and make for the Azores in order to reach Lisbon, steering a vast, semi-circular course."
[48] Guilmartin, 78.
Eane's 1434 voyage was his second attempt at rounding the cape; his first was diverted to the Canaries.
[49] Rush, 47.

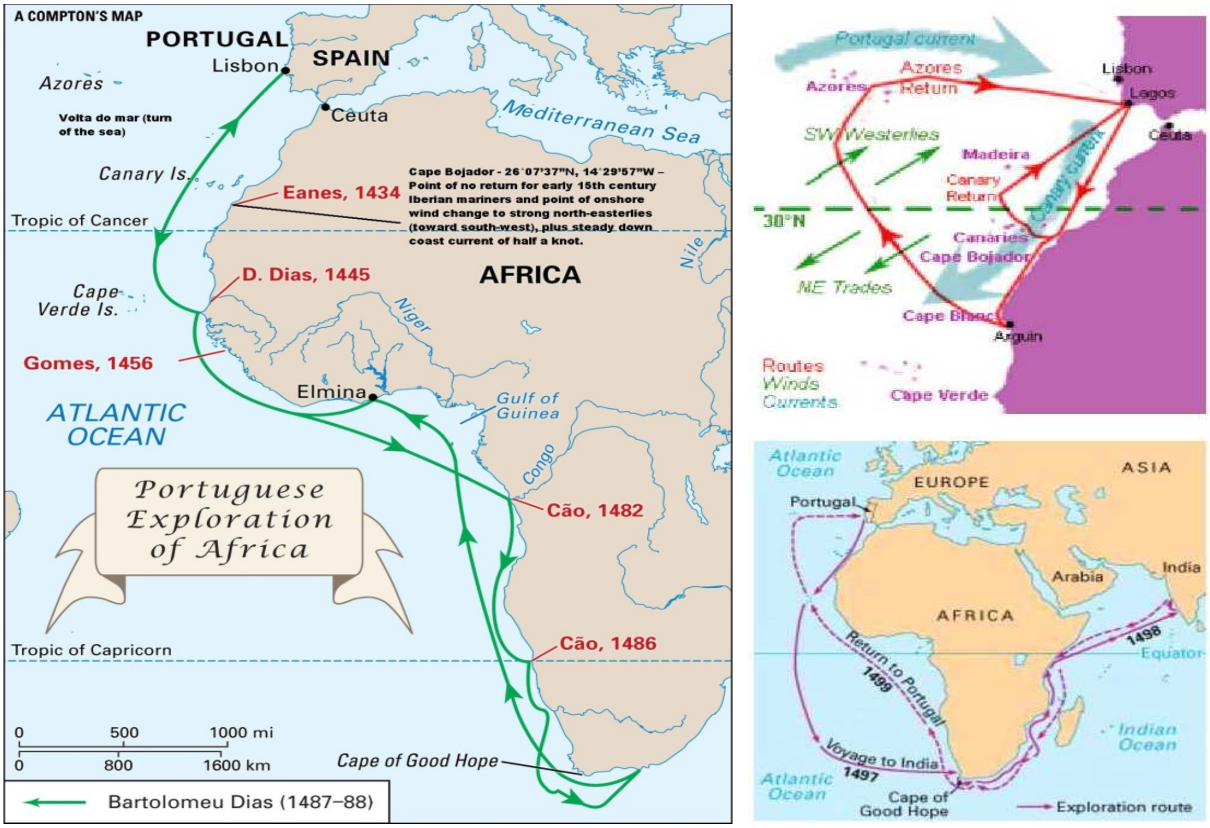
But before jumping too far ahead and assessing the program Henry had assembled at Sagres, we will return to the cape which hitherto had remained the southern edge of European experience.

John Law contends that defeating Cape Bojador – the point of no return – required three types of technological innovations:

(1) The mixed-rigged sea going vessel – ability to convert multiple wind conditions and survivable; sails for power reduced crew and increased cargo room
(2) The magnetic compass – freed sailors from coast hugging
(3) Sailing out to sea to obtain more favorable winds to return home – "It was the invention of this circle, called the *volta* by the Portuguese, that marks the decisive third step." [50]

The *volta do mar* or 'turn of the sea' (or 'return from the sea') was a discovery of the atmospheric and hydrologic oceanic rotation driven by the trade winds and the earth's rotation. The North Atlantic Gyre – necessary for Henry's sailors' return features a clockwise rotation of current and wind off shore. In the South Atlantic, the South Atlantic Gyre rotates counter-clockwise and required a westerly course to almost Brazil for outbound Indiamen. The variables or calms center on the Equator. These wind patterns created the 'long ocean tack' or the 'Guinea tack' needed to avoid the winds and currents that run south and southwest impeding the return of northbound vessels – the further south the caravels headed along the northwest African coast, the farther westward they needed to head out to sea in order to return.[51] This requirement to go far out to sea, days if not weeks from any landmark, required something hitherto novel; the ability to ascertain one's location at sea with no land for sightings.

[50] Law, "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," 118-119. Similar gyres exist in the Pacific and were essential for Spain's Philippine Galleon.
[51] Rush, 48.



Map 3.2. Portuguese discovery of the mechanical secret of the Atlantic: initiated by Prince Henry the Navigator in the early fourteenth century, Portugal's eight decade quest to open a seabound trade route to India is depicted above.[52] The map on the left chronicles the sequence of African coastal progress which was dependent upon the discovery of the wind and current paterns of the Atlantic Ocean. The diagram on the upper right illustrates the North Atlantic Gyre and Portuguese *volta do mar* (return from the sea), where winds and currents rotate clockwise and necessitate going farther off shore towards the west the further south one travels to ensure return. The South Atlantic Gyre rotates counter-clockwise and requires sailing vessels to plot a westward course almost to Brazil for outward journeys to India as is depicted here in Vasco da Gama's epic journey closing the fifteenth century (lower right).

For this task, the Portuguese assimilated navigational tools and techniques from across the world to guide their caravels and developed a new science of astronomical navigation. This navigational feat was nothing short of revolutionary. The eminent historian of navigation, E.G.R. Taylor identifies the first three thousand years of documented sea travel as the Primitive Navigation Period. Lasting from antiquity to the end of the first millennium AD, its origins can

[52] "The Portuguese," Kids.britannica.com, https://kids.britannica.com/students/article/exploration-of-Africa/543378/297848-toc and "Portuguese India Armadas," Wikipedia.org, https://en.wikipedia.org/wiki/Portuguese_India_Armadas#/media/File:Map_of_Portuguese_Carreira_da_India.gif and Gaggara, Naveen, "Geographical Hero: Vasco da Gama," Brawo8.blogspot.com, https://brawo8.blogspot.com/2012/08/geographical-heroes-vasco-da-gama.html.

be traced to Egypt, the Greeks, and the Phoenicians. This type of navigation was characterized by a reliance on observation (sky, shore, waterfowl, wind, ocean depth, color, and current) and the use of lead and line (soundings in unknown coastal areas). Although the Greeks may have used an early proto-rutter (a sailing log with identified landmarks) and primitive charts, sea travel in these years was primarily coastal, regularly familiar, and small in scale.

The first historical deviation from this norm in the west occurred in the Mediterranean contemporaneously with a similar seaward expansion in China. Taylor's First Navigational Revolution was a thirteenth century phenomenon that had its origins in the reawakening of Europe. It was enabled by a revival of the study of mathematics (geometry and spherical trigonometry) and astronomy in the West and by the discovery of polarity in iron ore (and the derivative magnetic compass). These discoveries led to expanded sailing and galley trade, "However, the point worth notice here is that these long open sea courses demanded pilots and masters skilled in the use of sailing directions, compass and chart."[53] These new navigation methods greatly expanded Mediterranean trade and opened up the coastal trade with the peoples of the North Atlantic and Baltic. However, chart and bearing navigation was only good for the known, for reliable weather, and for short durations away from land. Although aided by advances in astronomy, no astronomical instruments were regularly carried on board in this period.[54] Moreover, Taylor's 'revolution' was not a planned or directed effort.

Unlike its thirteenth century predecessor, Taylor's Second Navigational Revolution was however a clearly orchestrated program with a distinct objective. Launched in fifteenth century Portugal, the small kingdom harnessed the accumulated astronomical, geographic, and mathematical knowledge of both antiquity and the Mediterranean world and targeted it towards a

[53] Taylor, *The Haven-Finding Art: A History of Navigation from Odysseus to Captain Cook*, 109.
[54] Ibid, 121.

navigation that featured "finding and running down the latitude."[55] They developed a system of applied science, by taking the esoteric and making it practical, and by training a cadre of pilots that could not only apply this knowledge at sea, but who could gather data over decades by exploration and instrument, which they returned to the metropolis for analysis and future use. Using the sailing tools of the day and astronomical instruments simplified for seaborne use, they were able not just to use the heavens for referencing a bearing, but they were able to use it to fix their position at sea. This ability to sail without reference to land was a distinct factor in making long-distance oceanic travel on the Atlantic possible.

The Portuguese astronomers and navigators at first focused upon the pole star as had been done since antiquity in the northern hemisphere. But they did not just use it as a guidance point. Rather, by comparing it to documented astronomical observations, they used it as a reference point from which to fix their location. Eric Ash, in his *Power, Knowledge, and Expertise in Elizabethan England* notes that this technique was effective only in the northern hemisphere,

> "As the Portuguese sailed ever further to the south, the pole star sank ever lower in the sky, and it finally disappeared below the horizon as they crossed the Equator. Needing a new method that could be used in southern waters, they developed a sophisticated technique for calculating their latitude using the altitude of the sun at noon and its location along the ecliptic (which depended upon the time of year)."[56]

The Tudor explorers would experience a similar dissatisfaction with sailing by the pole star in artic waters. William Bourne in his late sixteenth century navigational writings would note that

[55] Taylor, *Haven-Finding*, 44, is clear to distinguish between sailing by the Sun or stars and 'astronomical navigation'. "It is necessary of course to distinguish between the sailor's use of the Sun and star to divide the circle of the horizon – merely to orient himself that is to say – and the use of heavenly bodies to find position on the Earth's surface, in other words the latitude. The one demanded simple observation, while the other involved measurement. It required, besides, logical thinking behind the measurement, and the capacity to compare measurements, and to understand their significance."
[56] Ash, Eric, *Power, Knowledge, and Expertise in Elizabethan England,* 99.

once one sailed north of England, sailing by Polaris became problematic, since it sat too high in the sky for usefulness in determining latitude.[57]

The Portuguese used the compass (a lodestone of possible Chinese origin, coupled with an Italian wind rose), the Mediterranean astrolabe, and Italian portolan charts to guide and record the details of their voyages. They eventually developed the quadrant to replace the land based astrolabe in ascertaining latitude by solar and stellar observation (by measuring the angle above the horizon of certain known stars or the sun). Rush notes that "in the last years before Henry's death in 1460, we find the first consistent mention of the use of the quadrant on board the Portuguese caravels." [58] Moreover, in addition to adapting astronomical instruments for seaborne use in their project, John Law has argued that;

> "The Portuguese problem was to build a new navigational context for their vessels that was less dependent on European geography, one that would render their vessels independent of a broader geographical environment, and hence make possible an undistorted system of global communication and control."[59]

In order to free European vessels from the constraints of their home waters King *Jao* II convened a commission in 1484 to specifically apply astronomical science to the practical task of oceanic navigation. Rush summarizes the Portuguese problem,

> "The giant distances out of sight of land introduced by Henry's navigators forced the Portuguese to bring the extensive astronomical knowledge and sophisticated instruments of the court astronomers within the reach of common sailors – heretofore not considered a profession to merit access to them."[60]

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[57] Taylor, E.G.R., editor, *A Regiment for the Sea*, 13, introduction to William Bourne's *An Almanacke for three Yeares.* In her introduction to Bourne's 1574 edition of *A Regiment for the Sea*, Taylor defines pole star latitude determination: "Latitude is directly given by the height of the Celestial Pole above the observer's horizon. The Pole is by definition always 90º from the equinoctial, therefore by finding the height of the equinoctial above the horizon and subtracting it from 90º the latitude is obtained."

[58] Rush, 49

[59] Law, "On Methods of Long Distance Control," 7.

[60] Rush, 49.

This commission simplified astronomical practice and codified its execution in manuals written specifically for their pilots.[61] Once trained, these early pilots became active participants in the project and on each voyage gathered information for the commission.

The data they meticulously gathered from their voyages became highly prized "state secrets."[62] During the mid-fifteenth century they noted the seasonal clockwise and counterclockwise rotation of wind and current directions in the North Atlantic and South Atlantic respectively. They also catalogued the regular winter gales near the Azores and the dangerous lack of winds in the equatorial latitudes known as the doldrums or variables.[63] Over decades, the caravels sailed out of Portugal and recorded the physical realities of the African coast and the

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[61] Law, "On Methods of Long Distance Control," 9, "In 1484 King John [Joao] II convened a small commission and charged it with the task of finding a method for navigating outside European waters. … These four men, and probably in particular [Jose] Vizinho, were responsible for one of the earliest successful practical applications of scientific knowledge to practice: the *Regimento do Astrolabio et do Quadrante*." In addition see: Law "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," 124-126, where he summarizes this specific program to translate science to practical navigation:

(1) simplification of astrological instruments – astrolabe and quadrant – to determine altitude

(2) "social engineering" by King John [*Jao*] II

(2.1) "convenes a 'scientific commission' to find improved methods of measuring the *altura*. … The convocation of a 'scientific commission' for the purpose of converting esoteric scientific knowledge into a set of widely applicable practices is already remarkable."

(2.2) production of handbook with detailed instructions and tables – *Regimento do Astrolabio e do Quadrante* – with its publication, the commission was "able to effect that transformation by producing a set of rules for the calculation of the latitude by semi-educated mariners."

(2.3) "it was the mariners who constituted the weakest link [in the new scientific navigation]. … It was difficult, although not ultimately impossible, to create a new social group necessary for closure, the astronomical navigator." – navigation classes and royal licensing traced to early sixteenth century and possibly late fifteenth century

[62] Swan, Claudia, *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, 224-225, eventually the Portuguese sole possession of these scientific secrets of the South Atlantic would be broken. She relates the story of Jan Huyghen van Linschoten, a Dutchman in the service of Portugal who helps to break their monopoly by providing the Dutch with "Portuguese state secrets"; navigational and cartographical information … fiercely protected by Portugal, in 1596.

[63] Russell-Wood, *The Portuguese Atlantic, 1415-1808*, 96.

Klein, 51, before 1470s, Portuguese learn to sail offshore into South Atlantic to pick up the northwest trade winds – brings them up to Azores making return voyages possible.

The variables are sometimes referred to as the 'doldrums', but this term stems from the characterization of a ship being in the doldrums while becalmed in the zone of variable, and often non-existent winds along the equator. This area, the Intertropical Convergence Zone, is a low-pressure area created by the convergence of the wind systems north and south of the equator. It is where the trade winds meet between approximately latitudes 5° north and south.

South Atlantic, and in consequence they grew a national knowledge database for future caravel captains and navigators.

John Law summarizes the accomplishments of the early Portuguese oceanic exploration system in regards to the science of astronomical navigation:

> "In the 1480s they developed a practical method for astronomical determination of latitude on board ship. The general idea was that if the *altura*, or height above the horizon, of the sun or a star (normally the Pole Star) could be determined and compared with the known *altura* of the port of destination, then the ship could sail north or south until it reached that latitude, and then sail, as appropriate, east or west in the certainty of finding its destination."[64]

However, their methods were imprecise and they were predicated on the state of science in their day. In order to ascertain latitude the pilot would take his reading of the Sun's altitude at noon above the horizon with a mariner's astrolabe, or after about 1514, with a cross staff. He would do this by shooting the point of the sun's transit apex where it crosses the longitudinal meridian – the point at which it ceases to rise in the sky, but has not yet started its descent. He would subtract the known seasonal solar declination for that particular day by referencing a series of declination tables prepared for him by metropolitan cosmographers, which in turn had been generated from ephemerides generated by court astronomers (see Chapter 4). He would then subtract the resulting difference from 90º; the final result would be his current latitude. As we will see in Chapter 5, the Iberian methods of deriving daily declination were somewhat complicated and required training, mathematical skills, and knowledge of the zodiac. The instruments used on the deck of a small wooden ship in mid-Atlantic were imprecise even in the

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[64] Law, "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," 122.

Gómez, 48-49, examines the classical Greek roots required to develop 'running down the latitude' technology – Greek methods for ascertaining latitude from Strabo's *Geography*:

(1) Observational – relying on theory that equal latitudes will have similar environments, climates, crops, temperatures, flora and fauna [this *does not account for altitude, land mass, weather patterns, proximity to ocean, etcetera. This would have to wait for Alexander von Humboldt*].

(2) "Measurements afforded by sundials and dioptrical instruments" – reliance on astronomical and solar observations and the principle of refraction

best weather conditions, and lastly, the declination tables themselves were calculated for specific longitudes and required interpolation for significantly different longitudes than that of the metropole for which they were created. However, calculating longitude at sea was impossible at this time. The difficulties the Portuguese encountered in precisely fixing their latitude or even guessing at their longitude would require future advances in astronomy, instrument making, and mathematics on shore and afloat. The requirement for technological navigation solutions was engendering development as the rewards at sea for successful innovations were manifest for budding imperialists, merchants, and pirates alike.

The Portuguese cosmographers simplified astronomical calculations and instrument technology for the user-focused single purpose of determining one salient fact: determining one's latitude at sea while out of sight of land. This process of reducing intellectual knowledge and craft skills for more and more people of lower station to obtain a directed end was novel and spectacularly successful. It would also breed its own remorseless logic of continuing intellectual automation as the sixteenth century author William Bourne demonstrated in his Iberian inspired *A Regiment for the Sea (1574)*. His Sixth Rule for mariners (which follow his simplified and pre-calculated declination charts) is aimed not just at highly trained and licensed pilots, but at common seamen. In it, he details the advantages of the cross-staff, the simplified successor to the Portuguese mariner's astrolabe and makes plain the process of determining altitude to even people lacking any experience of the sea,

> "Nowe to take the heigth of the Sunne, to knowe thy Altitude of the Pole above the Horizon, doe this: Firste set the Sunne with a compasse, to knowe when that the Sunne commeth near unto the Meridian: as soone as you see that the Sunne is come unto the South and by East, then beginne to take the heigth of the Sunne with the crosse staffe in this manner: Put the Transitorie upon the long staffe, then set the end of the long staffe close at the corner of your eye, winking with your other eye, and removing the Transitorie forwardes or backwardes, until you doe see the lower end of it (being just with the Horizon) and the upper ende of it, (being just with the middle of the Sunne) both

> to agree with the Sunne and the Horizon at one time: and so have you the true heigth of the Sunne: this done, Stil observe y^e same, until you see the Sunne at the highest and beginning to descend, and then have you finished."[65]

Bourne caveats his instructions with a warning about using this method on the Sun when it is above 50º in the sky; but the method itself is presented void of theory, aimed solely at mechanics. He goes on to explain the use of the astrolabe when it is the superior instrument (60-80º solar altitude – its more common altitude in southern waters),

> "Holde the Ring of the Astrolobe upon one of youre fingers, and turne the Alhidada [the moveable cross-piece pinned at the center] uppe and downe, until you see the shadowe of the Sunne pearse or passe thorough both the sightes thereof, being sure that the Astrolobe dothe hang upright, whiche you may prove in this manner: Looke at howe many degrees and minutes the Alhidada dothe stande upon the Astrolobe, then turne the Alhidada unto the same number of degrees and minutes on the other side of the Astrolobe, and then taking the heigth of the Sunne againe, if it doe agree as it did before, then the Astrolobe doth hang upright. but if it doe not, then it dothe not hang upright."[66]

As is evident from this passage, Bourne is giving user instructions, tips, and correction advice. He goes into greater detail in the pages that follow to help the intended user to correct common errors in sighting or with errors in the instruments themselves. Unlike its Iberian predecessors, Bourne's *A Regiment for the Sea* is a manual focused primarily on efficacy and ease of use. It follows to a logical conclusion the Portuguese program of creating navigation tools that do not require theoretical knowledge or the ability to craft instruments on the part of the user. The thinking is left to the metropolitan intellectual. The doing and the danger is left to the common sailor at sea. We will return to Bourne, and his Tudor contemporaries and their quest to imitate

[65] Bourne, William, *A Regiment for the Sea, 1574*, The Sixth Chapter or Rule, 207-208. He notes that the astrolabe is still preferable when the Sun's altitude is "very high at .60.70. or 80. Degrees."

[66] Ibid, 208-212, also provides insight on how to protect your vision while having to sight on the sun, how to address cross-staff errors, how to calculate the true Meridian on land and upon the sea, and how to calculate and adjust for compass variation by using stellar and lunar observation.

Taylor, *The Haven-Finding Art*, 166 and 175, adds some insight into the history of the navigational cross-staff noting that "Vasco da Gama had brought home this instrument, the Arab *kamal* [*travedetas de la India* – according to Cabral's men], and it is clear that it was considered to have some advantages at least over the astrolabe." The Portuguese cross-staff eventually replaces the astrolabe and quadrant and its lineage can be traced from the Greek *dioptra* through the *kamal*. "The instrument had its drawbacks: it was for instance more useful for moderately low latitudes than for high ones and for [sighting] stars [rather] than for the Sun."

and improve upon the Iberian program of astronomical navigation, but first let us return to Portugal and the southern Atlantic.

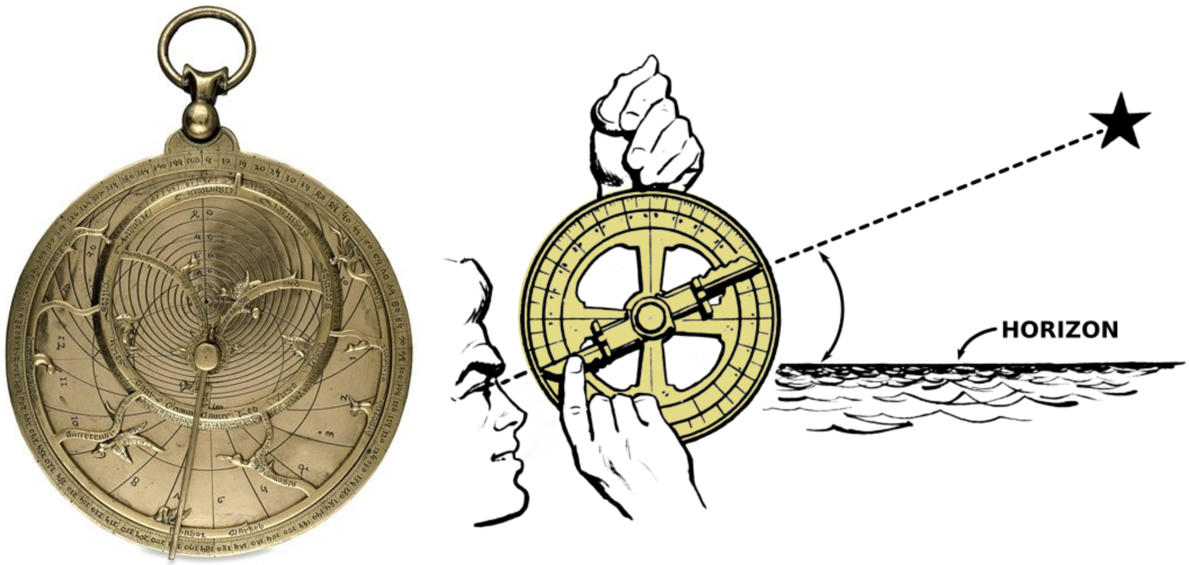

Figure 3.6. Evolving instrument technology in ascertaining solar or stellar altitude. [67] The Mariner's astrolabe was developed from the astronomer's terrestrial and more complicated ancestor, specifically for pilots measuring the altitude of celestial bodies at specific designated times, by the Portuguese metropolitan cosmographers.

LATITUDE = 90º – (Solar Altitude – Seasonal Declination) [68]

[67] The Chaucer astrolabe © Trustees of the British Museum**,** Britishmuseum.org, http://www.britishmuseum.org/research/collection_online/collection_object_details/collection_image_gallery.aspx?assetId=35125001&objectId=54862&partId=1.
[68] Foresman, Pearson Scott, "Mariner's Astrolabe," wikimedia.org, https://upload.wikimedia.org/wikipedia/commons/9/90/Astrolabe_%28PSF%29.png.

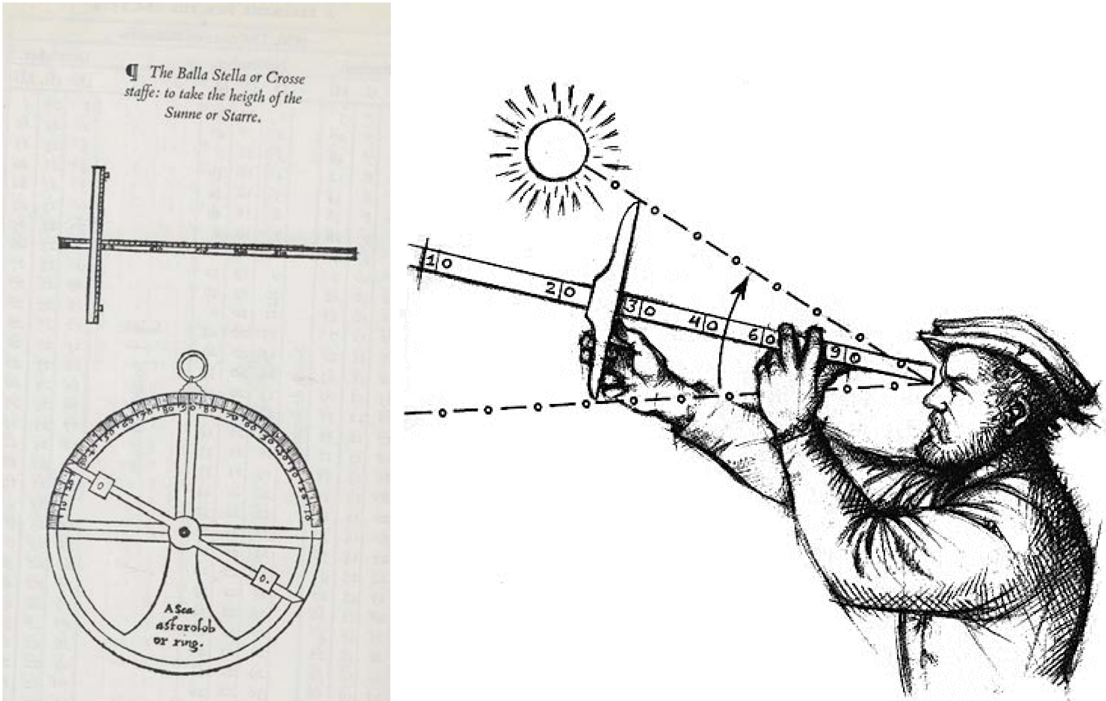

Figure 3.7. William Bourne's instruments and instructions for ascertaining solar or stellar latitude from *A Regiment for the Sea*, 1574. Bourne explains why the cross staff is a more reliable instrument for his marine element: "To take the true height of the Sunne at the Sea, the beste way is, to doe it with the crosse staffe: for that sea is moveable, and causeth the Shippe to heave, and sette little or much: and also upon the crosse staff the degrees be larger marked than the Ring or Astrolobe: and in a large instrument an errour is seene sooner and better than in it is in a small instrument."[69] "The use of the cross-staff for navigation is believed to have first been suggested in 1514 by the German mathematician *Johannes Werner* (1468-1522)."[70]

Opening of the Atlantic and Indian Trade Routes

The maritime African trade program of Henry the Navigator had morphed into a program of trade (often coercive) directly with Africa and Asia. By 1487 Bartholomew Diaz had rounded the Cape of Good Hope and the program had reached its fruition with Vasco da Gama's return from India at the end of the fifteenth century. Da Gama and his successors would expand their Atlantic hydrographical canon with knowledge of the seasonal monsoon wind patterns of the Indian Ocean, often supplied, as in the case of da Gama himself, by Arab or Indian pilots, or by

[69] Bourne, William, *A Regiment for the Sea, 1574*, The Sixth Chapter or Rule, 207.
[70] A cross-staff in use (image credit: Canadian Museum of History). "A Brief History of Navigational Instruments," Technologyuk.net. http://www.technologyuk.net/physics/measurement-and-units/navigational-instruments.shtml.

preceding overland Portuguese reconnaissance and intelligence missions in the Middle East.[71] By 1511, the Portuguese had taken control of the 'Old World's' other great civilization sphere choke point, by capturing the Strait of Malacca. For virtually the next century, the Portuguese would dominate African and Asian trade to Europe thanks largely to the caravel exploration program and the development of the workhorse of the *Carreira de India*, the carrack.

The Portuguese carrack performed the dual function of transport vessel and fighting ship. These 'Indiamen' were heavily armed merchant ships, and in their day, they were the largest vessels afloat (up to 2000 tons).[72] They had four distinct characteristics that made them indispensable components of the Portuguese trade program. (1) They were "virtually impregnable to attack by boarding from small craft" and boasted escalading castles fore and aft which produced devastating crossfire; this combined with a high freeboard, discouraged boarding. (2) They had a large cargo capacity for the time period and when well provisioned, were free to avoid shore and regular stops. (3) They used a "combination of square and (triangular) lateen sails … successful attempt to obtain versatility in a range of wind conditions. …They made it possible to use the winds in ways that had not earlier been possible by transforming those that might previously have been dangerous, or simply adverse, into forces

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[71] Crowley, *City of Fortune*, 348, notes that for Venice, *Bartolomeu Dias* rounding the Cape of Good Hope in 1487-1488 meant the twilight of their Eastern spice trade monopoly was quickly approaching. He notes that the Portuguese determination to assemble a practical hydrographic canon was preceded by years of overland reconnaissance of Egypt, the Indian Ocean and Arab trade routes. From this they developed a detailed understanding of the monsoon seasonal winds [this was part of the proto-scientific oceanic, hydrological, and meteorological study that characterized the Portuguese Atlantic program].

Taylor, E.G.R., (editor), *A Regiment for the Sea*, 12, 121, cites T. A. Chumolsky for identifying Ahmad Ibn-Majid, "the so-called 'Pilot of Vasco da Gama", who led the Portuguese to India in 1498."

[72] Russell-Wood, *The Portuguese Empire, 1415-1808: A World on the Move*, 28-29, also referred to as a *náo*, one of the largest carracks of the period was the *Madre de Deus;* captured by the English in 1592 on its homeward trek, it was 1600 tons. In the early seventieth century carracks of up to 2000 tons were mentioned.

Glete, 80-81, notes that "the huge *naus* (often called carracks) were a return to the fifteenth century technology when size rather than guns served as defense of cargo carriers. Size was useful in Asia, where the threat often came from small ships using boarding tactics, but it made the ships unwieldy sailors and vulnerable to more maneuverable European ships armed with guns." This vulnerability of Iberian shipping designed to survive Asian seas will be addressed in more detail in Chapter 7 regarding the rise of the northern protestant pirate navies.

that contributed to the projects of the Portuguese by driving their vessels towards their destinations." And (4) they required relatively small crews.[73] The carrack was an essential component of the Portuguese enterprise of long-distance trade, but its design was a product of that system, not its driver.[74]

Figure 3.7. Reconstruction of a Portuguese Carrack or Nao of the *Carreira de India*.[75] Like the caravel, note the mixed rig of square and lateen sails to harness most wind conditions; the main and fore mast are square rigged, the mizzen mast carries a lateen rigged triangular sail. Unlike the fully rigged ship of later centuries, most masts ship only a single sail. Note the high freeboard (side walls above the water), fore and aft fighting castles, upper fighting platform, and an almost tub shaped hull of large carrying capacity in comparison to the caravel. These features provided the carrack with the defensive capacity against boarding attacks in Asia and the cargo capacity

[73] Law, "On Methods of Long Distance Control," 4-5.
Guilmartin, 92-97.
Russell-Wood, 28-29.

[74] Law, "Technology and Heterogeneous Engineering," 128, notes that "it is important not to fall into the trap of technological determinism and assume that it was the technology alone that brought about Portuguese success. As was the case for the caravel, the *volta*, and the practice of astronomical navigation, the durability of the armed warship was a function of a collision between the forces of the Portuguese system builders and those of the seas, and in this case, the Muslims."

[75] "The Lost Treasure of *Flor de la Mar*, *Flower of the Sea*," Ancient-origins.net, http://www.ancient-origins.net/history/lost-treasure-flor-de-la-mar-flower-sea-006236.

required for long landless sea treks and profitable trading voyages, but left it susceptible to the depredations of rival power piracy back in the North Atlantic where northern sailors used more weatherly heavily gunned ships and even galleons designed specifically for hunting large lucrative prey. This ship, the *Flor do Mar* (Flower of the Sea) built in Lisbon in 1502 was one of Portugal's largest ships of its day at approximately 400 tons. It reportedly sunk laden with treasure off Sumatra or in the Strait of Malacca on its homeward voyage.

New Science, Monopolies, and Jealously Guarded Secrets

The Portuguese were adept at incorporating useful technology, science, and cosmography from across the Mediterranean and Northern Europe.[76] However, they assiduously guarded the fruits of their research and trade programs. By the turn of the sixteenth century, they had established the *Casa de Guinea e India* in Lisbon to regulate pilot training and catalogue and protect their cosmographic secrets.[77] The Portuguese state supported, manned, and financed the spice trade on the *Carreira de India.*[78] This state run enterprise jealously guarded its prerogatives and the knowledge it had generated. However, in order to use this knowledge effectively, it had to train pilots, shipwrights, cartographers, cosmographers, and assorted technicians that often became the objects of foreign solicitation – both financial and forceful – from both state agents and competitive tradesmen.[79] They also faced competition on the Iberian

[76] Russell-Wood, *The Portuguese Empire, 1415-1808: A World on the Move*, 17, observes that "In four distinct instances, the Portuguese were not themselves inventors but inherited the fruits of earlier discoveries. The positioning of a central rudder on the stern post of the keel had first appeared in the Baltic in the mid-thirteenth century. Secondly, shipboard application of the magnetic needle and compass had arrived in Portugal from the Arabs … attributed to the Chinese … twelfth century. Thirdly, the triangular lateen sail had originated in the eastern Mediterranean in the early Middle Ages. Fourthly, the portolan chart with compass or wind roses and rhumb lines … Italian seamen by the early 1300s."

[77] Law, "On Methods of Long Distance Control," 10, cites Waters, David W. *The Art of Navigation in England in Elizabethan and Early Stuart Times*, 62, who notes that the *Casa* "included an organization equivalent to a modern hydrographic office at whose head was a Cosmographer-in-chief. He was assisted by cosmographers whose business it was to draw and correct charts and to compile books of sailing directions and, no doubt, as in the similar Spanish organization of the sixteenth century, to assist in the instruction of pilots."

[78] Glete, 80, notes that the "pepper trade became a royal monopoly (periodically leased to private investors) and all trade around Africa had to be carried in armed merchantmen owned by the king."

[79] Russell-Wood, 74, adds "Officers with technical skills were highly prized and were moved from one assignment to another in the Portuguese empire." 85-86, "Artisans with special skills – stone-masons, carpenters, caulkers, smiths – were moved remorselessly from one center of activity to the next in the royal service, building, repairing, or supervising work on official residences, barracks, fortresses, trading posts, docks and wharves, mints, bridges, roads, and even water fountains. … This mobility by artisans with special skills could be harmful to the Portuguese cause. Some artisans possessed skills which might be attractive to local potentates and this was notably the case of gun makers in Portuguese India."

peninsula throughout the course of their explorations. The Portuguese project, always dependent upon expertise from throughout Iberia – Catalan pilots, mathematicians from Castile, Jewish astronomers who had survived the *Reconquista* – was quickly emulated by the Spanish crown. Portugal and Spain had to share the Atlantic. They would also have to fend off competition and intrigue from both northern and eastern enemies.

The Portuguese and Spanish, despite all their success, could not afford to focus solely on the Atlantic while Muslim advances were steadily being made in the Mediterranean and Eastern Europe. Roger Crowley, in his *Empires of the Sea: The Siege of Malta, the Battle of Lepanto, and the Contest for the Center of the World,* observes that one result from the 1522 fall of Rhodes was expanded Ottoman cosmographic knowledge:

> "a Turkish navigator called Piri Reis – Piri the Captain [or alternatively Admiral] … had already produced for the sultans a world map of astonishing accuracy, which included the Columbus maps. The *Book of Navigation* did something more immediately useful. Alongside accounts of the discoveries of Columbus and Vasco da Gama, it contained a practical guide to sailing the Mediterranean, drawn from Piri Reis's voyages. Two hundred [and] ten portolan charts – diagrammatic maps with sailing instructions – expounded the coastal seas … of the infidel to the straits of Gibraltar. … His book was a blueprint for fighting naval wars."[80]

Piri Reis had never sailed on the Atlantic, but his maps were state of the art for their day, and can only have been produced after assiduously collecting enormous amounts of data from his Christian rivals.[81] Protecting nautical knowledge was not just an economic or prestige imperative for the Iberian Atlantic powers – it was an issue of existential importance.

[80] Crowley, *Empires of the Sea*, 34, the *Book of Navigation or Kitab-i Bahriye* (1521), revised 1524-1525, was by Piri Reis presented to Suleiman I and derived from his own Mediterranean knowledge and purloined Iberian secrets.
[81] Blake, John, *The Sea Chart: The Illustrated History of Nautical Maps and Navigational Charts*, 15, speculates that Piri Reis' sources for his 1513 world map could also have included Chinese maps from the aborted Ming Dynasty era of exploration in the early part of the fifteenth century.

Map 3.3. A late 16th century copy of the map of Europe from *Kitab-i Bahriye.* [82] The *Navigation Book* was originally compiled by Piri Reis (Hajjı Ahmed Muhiddin Piri) for Suleiman I in 1521. The naval intelligence provided by this collection of navigation techniques and portolan charts made it indispensable for both future Ottoman invasion armadas and corsair raiding fleets. This third edition map includes the Black Sea for the first time. The original maps owed their accuracy to Reis' examining maps by Columbus and the Portuguese, and this edition was heavily influenced by the Italians and the great Dutch cartographer Abraham Ortelius.

[82] Library of Istanbul University, No: 6605, Wikimedia.org, https://en.wikipedia.org/wiki/Piri_Reis#/media/File:Piri_Reis_map_of_Europe_and_the_Mediterranean_Sea.jpg.

Map 3.4. The Piri Reis *mappa mundi* depicting the central Atlantic basin circa 1510.[83] This world map was compiled in 1513 from military intelligence by the Ottoman admiral and cartographer Piri Reis. Approximately one third of the map survives; it shows the western coasts of Europe and North Africa and the coast of Brazil with reasonable accuracy. Various Atlantic islands, including the Azores and Canary Islands, are depicted, as is the mythical island of Antillia and possibly Japan. The historical importance of the map lies in its demonstration of the extent of exploration of the New World by approximately 1510, and in its claim to have used Columbus's maps, otherwise lost, as a source. It used ten Arab sources, four Indian maps sourced from the Portuguese, and one map of Columbus. In his notes appended to it is written "the map of the western lands drawn by Columbus." Note that among other 'unknowns' of the period, South America is connected to an immensely large and excessively northern Ptolemaic *Terra Australis Incognita*.

[83] Library of Topkapi Palace Museum, No. H. 1824, Wikimedia.org. https://en.wikipedia.org/wiki/Piri_Reis_map.

Connections

We have examined a number of reasons why the Atlantic program developed in Portugal, but this evolution was not inevitable. Braudel believed that even though North Atlantic trade had been initiated by the peoples of the Mediterranean in the fourteenth century, that it was "inevitable" that this trade would be taken over by the peoples of that region. He states that the "struggle for world domination began at the end of the fifteenth century."[84] But was it inevitable that this struggle's progenitor and its first victor be Portugal? A. J. R. Russell-Wood highlights that the "conducive geography of Portugal, its estuaries and bays that can easily accommodate ocean going vessels and numerous ports to service ships [were] more plentiful than anywhere else in Europe."[85] He also notes that Portuguese dominance came "almost by default". The Portuguese faced a virtual absence of European challengers after the 1494 Treaty of Tordesillas with Spain assigned each a respective sphere of influence, until the Dutch established a presence after shaking off the Hapsburg yoke in the early seventeenth century. But geography alone is not destiny. Portuguese success was not just the product of a favorable Atlantic coast line; or of technological breakthroughs in shipping, gunnery or astronomical observation, but rather in its system of incorporating each of these indispensable discoveries into a social framework that exploited their capabilities.[86] Culture, inspired leadership, technological adaptation,

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[84] Guilmartin, 83 and Braudel, 140.

Seed, Patricia, *American Pentimento: The Invention of the Indians and the pursuit of Riches, (Public Worlds, Volume 7),* 138.

[85] Russell-Wood, 97, 104, notes as well that various Papal Bulls protected their trade from other Catholic Europeans.

Klein, 76, notes that the Dutch do not seriously challenge Portuguese trade in Africa until they form the Dutch East India Company, the *Vereenigde Oost-Indische Compagnie or* VOC in 1621. He also notes the Portuguese Indian monopoly lasts until the English (1622) and Islam (1648) break it by seizing key bases in the Arabian Sea (69).

[86] Law, "On Methods of Long Distance Control," 2, highlights the critical nature of the Columbian landfall and the Portuguese arrival in the Indian Ocean at the close of the fifteenth century as defining moments heralding the rise of Europe to a global dominance lasting five centuries. He acknowledges that extensive study of the period regarding politics, economics, and military strategy rightly exists. However, he notes that the study of the means to European ascension – naval architecture, navigational science and ordnance production – have been left to technical specialists in maritime history. Law sees this as problematic, arguing that "it is not possible to understand this expansion

perseverance, and raw courage launched the caravels and thereafter reaped the rewards of opening up the Atlantic world and establishing maritime links with Africa and Asia.

It is in the Portuguese nautical program that we see the early emergence of one of the quintessential modern mores of governance; specifically the targeting of scientific research to enhance the prosperity of the state. Medieval kingdoms and princes hitherto did not conduct decade's long research programs like the one launched by Prince Henry in the early fifteenth century. They did not direct the resources of the kingdom towards commercial ends and the fulfillment of that project as the mercantilist Avis kings Joao II and Manual I did to close out that century. Medieval kingdoms and princes assembled the resources of the state as Jan Glete has noted for war; either in defense of the realm or for the acquisition of new territories or the recapture of old ones. They involved themselves with dynastic marriage alliances and occasionally were embroiled in sectarian disputes. The Portuguese on the other hand, especially toward the end of this century, behaved more like one of the Renaissance Italian free trading city states; but with the resources of a medium sized medieval kingdom. Like the Genoese and Venetians, their maritime operation was not aimed at territorial acquisition and foreign dominion, but rather for securing monopolistic trade routes, privileges, and facilities.

Medieval states hitherto did also not concern themselves with preventing the flow of purely academic knowledge across borders. They did not develop techniques for making this knowledge practical for the use of men of 'low or mean' station. This program also required the elevation in importance of university educated men and as a result precipitated early challenges to the hierarchal feudal order. Lastly, we also see the long-term national commitment to the

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unless the technological, the economic, the political, the social, and the natural are all seen as being interrelated. … My argument is that the Portuguese effort involved the mobilization and combination of elements from each of these categories. Of course kings and merchants appear in the story. But so too do sailors and astronomers, navigators and soldiers of fortune, astrolabes and astronomical tables, vessels and ports of call, and last but not least, the winds and currents that lay between Lisbon and Calicut."

interests and objectives of the maritime and trade communities within the kingdom. Portugal succeeded because successive rulers over eight decades dedicated resources to the Atlantic project. We will note in future chapters that this sustained national commitment to maritime success was exceedingly rare, even more so as technological breakthroughs escalated costs, and that realizing the rewards of maritime acumen would require national resolve. As we continue our story we will observe the expansion of these embryonic modern characteristics in the dominant Iberian player, Castile, and we will assess their wholehearted embrace by Tudor England. However, before we continue our story in Iberia, we need to take a closer look at the theory behind and the development of the astronomical knowledge propelling these journeys.

CHAPTER 4.

Copernican Astronomy and Oceanic Exploration: The Scientific Revolution and the Age of Sail

Copernican Astronomy and Oceanic Exploration

Were Nicolaus Copernicus, Johannes Kepler, and Galileo Galilei indebted to Prince Henry the Navigator, Christopher Columbus, and Vasco da Gama or did these new astronomers enable the Iberian heirs of the first great explorers to build upon their achievements? Since the first breakthroughs in Portuguese astronomical navigation in ascertaining latitude at sea were based upon the theories and observations of classically trained Ptolemaic astronomers and cosmographers, was the new heliocentric astronomy even necessary for future developments in early modern navigation? Did the inertia of the emerging oceanic programs (including those spreading to the Protestant north) demand better science (or a more expansive scientific paradigm) or did brilliant new ideas help expand and propel the overseas project?

This chapter will attempt to ascertain if there was little, unidirectional, or reciprocal impact between the century long development of the 'New Astronomy' (Copernicus' axially rotating and solar orbiting earth, governed by Kepler's laws of planetary motion) of the sixteenth and early seventeenth centuries and the emerging astronomical navigation technologies of the fifteenth and sixteenth century Iberian oceanic explorers and their sixteenth and seventeenth century Protestant competitors. If such a relationship existed, was any directional impact large or determinative? To what extent did the new cosmographic theories and epistemologies of the period shape the emerging Portuguese, Castilian, and north Atlantic oceanic programs and to what extent did these programs, including their observations, discoveries, and technologies, impact the development and acceptance of the New Astronomy?

Ptolemaic Cosmography – 'a workable model'

We will focus on the linkage between the cosmographical aspect of early modern natural philosophy – roughly and anachronistically referred to as 'science' herein, and the emerging navigational technologies of the Age of Exploration. The astronomy and mathematics that enabled the fifteenth century Portuguese to guide their caravels down the African seaboard and return safely by taking advantage of the Atlantic current and wind patterns by accurately fixing latitude by measuring declination angles of the sun and the pole star belonged to the Ptolemaic and geocentric corpus.[1] Only its specific application, wedded to innovative ship design and national political will was different. The first great voyages of Columbus and da Gama predate the publication of Copernicus' *De revolutionibus orbium coelestium (On the Revolutions of the Heavenly Spheres)*, let alone its acceptance, but the expansion of the oceanic program depended increasingly on more reliable astronomy. Both the navigational end users and the astronomers of the sixteenth century were participating in revolutions in their respective fields. Princes and successful pirates alike were funding observatories to develop better astronomical tables (ephemerides) and more reliable mechanical methods for fixing location. This knowledge was the focus of national monopolies, national secrecy, espionage, and princely endowments. The rediscovery of the Aristotelian and Ptolemaic corpus that had provided the math and geography to launch the caravels was beginning to fall short of the new demands placed upon it, particularly in regards to astronomy.

[1] As noted earlier, there was not unanimity of thought in the classical world any more than there was during the High Middle Ages or is today. However, even though there were many schools of classical cosmographic opinion in the ancient Mediterranean world, the Aristotelian world view and the cosmography of his second century acolyte Ptolemy were authoritative in Middle Ages Western Europe. These men were the dominant authorities referenced by the Scholastics who at the time dominated the universities; their sobriquets were indicative, 'The Scholar' and the 'Great Geographer'. For the debates between the Humanists and the Scholastics regarding Strabo and Ptolemy, see Chapter 2.

Thomas Kuhn has noted of Ptolemaic cosmography (a realist compromise of pure Aristotelian physics and mathematical practice) that "… the two-sphere universe is a product of human imagination. It is a conceptual scheme, a theory, deriving from observations but simultaneously transcending them."[2] It was not, and still is not a bad theory, especially based upon sensory experience alone. Kuhn goes on,

> "The theory and practice of both navigation and surveying can be developed with great simplicity and precision from [the dual spherical] models [earth and stars respectively] …, and, since the model demanded by modern astronomy is far more complex, the two-sphere universe is normally used [today] in preference to the Copernican when teaching these subjects. … Evaluated in terms of economy, the two-sphere universe therefore remains what it has always been: an extremely successful theory."[3]

Returning caravels and carracks might bring back information conflicting with the precepts of The Scholar or the Great Geographer, but the discrepancies did not provide enough impetus to immediately unseat the medieval epistemology. In fact, even as evidence against the two-sphere model of the universe mounted, the model's practicality ensured its continued use. David Waters in his *The Art of Navigation in Elizabethan and Early Stuart Times,* notes that,

> "The classical explanation of the cosmos known as the Ptolemaic was common doctrine to the learned schoolman and pilot. Almost every navigational work of the sixteenth and seventeenth centuries contains a description of the Ptolemaic system. It remained standard into the eighteenth century."[4]

In addition to the sensory confirmation and the practical utility of the Ptolemaic system, its endurance can also be attributed to the lack of a coherent holistic opposing cosmography, at least for the first half century after the publication of *de Revolutionibus*. Copernicus' model was not presented as a metaphysical treatise and its absurd central premise, so opposed to everyday experience, had not yet been refined in such a way that it produced dramatically better data fitting observation. The new theory also lacked proponents.

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[2] Kuhn, Thomas, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*, 36.
[3] Ibid, 38 – see also page 37 for Kuhn's explanation of 'conceptual economy' – scientific theory as mnemonic aid.
[4] Waters, David W., *The Art of Navigation in Elizabethan and Early Stuart Times,* 41.

Nick Wilding has noted that, “that only around a dozen intellectuals might safely be identified as ‘Copernicans’ in the period before 1616.”[5] Robert Westman in his “The Astronomer's Role in the Sixteenth Century,” similarly notes that “Between 1543 and 1600, I can find no more than ten thinkers who choose to adopt the main claims of heliocentric theory.”[6] The old theory mostly worked, and the new had few followers, but Europe’s ships were pushing further and further out into the oceans and the astronomy that propelled this surge was becoming inadequate to the increasing demands placed upon it. In order to examine these demands, we must return to how the art of navigation was practiced up to the dawn of the sixteenth century.

The Spanish Astronomical Navigation Program

E. G. R. Taylor traces the history and development of navigation from antiquity to the eighteenth century Pacific explorations of Captain Cook through four major periods: the classical period of observational navigation, Renaissance navigation, the astronomical navigation launched by Portugal in the Atlantic Ocean, and finally the dawn of mathematical or scientific navigation. Despite the slow expansion of the reach of ships throughout each of these major periods, Taylor contends that sailors have from the earliest times, and with the most primitive technology, explored the open seas. Coastal sailing for efficacy and safety should not be confused with timid sailors ‘hugging the coast’ contra Braudel. The history of men on the sea

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[5] Wilding, Nick, “Manuscripts in Motion: The Diffusion of Galilean Copernicanism,” *Italian Studies*, **66:2** (July 2011), 223.

[6] Westman, Robert, “The Astronomer's Role in the Sixteenth Century,” 106.

Footnote #6 (pg. 136): List of said personages:

England	Thomas Digges, Thomas Harriot	
Italy	Giordano Bruno and Galileo Galilei	(burned & abjured respectively)
Spain	Diego de Zuniga	(Index)
Benelux	Simon Stevin	
Germany	Rheticus, Michael Maestlin, Christopher Rothmann, Johannes Kepler	

Mottelay, P. Fleury, xii, in his “Biographical Memoir” preceding his translation of Gilbert, William. *De Magnete*, quotes Henry Hallam noting that “[William] Gilbert was one of the earliest Copernicans, at least as to the rotation of the earth, and, with his usual sagacity, inferred, before the invention of the telescope, that there are a multitude of fixed stars beyond the reach of our vision.”

and their ability to select their course has always been both bold and inventive. This history is also by definition technological. We have examined the first two of Taylor's periods and the deliberate Portuguese launching of the third. However, as we have seen, they drew on sources from throughout Western Europe and especially Iberia for their project. Many of these individuals and their kingdoms had Atlantic dreams of their own. Taylor's Astronomical Navigation Revolution was enhanced and enriched by the Kingdom of Castile as they forged the world's first global empire.

Renaissance cosmography in Spain owed its paternity to the Portuguese Atlantic exploration project and a Humanist revival of "three classical intellectual traditions: Aristotelian natural philosophy … Euclidean geometry and Ptolemaic geography."[7] In the riverine port city Seville, the Spanish established in 1503 the *Casa de la Contratación* (House of Trade or Commerce – officially *La Casa y Audiencia de Indias*) which as Peter Dear has observed, "increasingly concerned itself with mathematical navigational techniques, training the pilots who sailed the routes to the New World, and gathering and coordinating related geographical and navigational information."[8] Alison Sandman, in her work "Controlling Knowledge: Navigation, Cartography, and Secrecy in the Early Modern Spanish Atlantic," illustrates the linkages between Iberian cosmographical theories of the day (as established at the *Casa de la Contratación*) and the navigational practitioners. She examines the issue of controlling geographic knowledge in the early modern period with reference to Atlantic cartography and navigational knowledge. Using Spain as her case study, she illustrates the conflicting goals

[7] Portuondo, Maria, *Secret Science: Spanish Cosmography and the New World*, 21, examines the humanist epistemological foundations of Renaissance cosmography (a holistic blend of geography, cartography, ethnography, natural history, history, and astronomy) in sixteenth-century Castile and its eventual mathematical empiricist offspring that emerged by the end of the Century of Discovery. The author also chronicles the concomitant role that secrecy played in state cosmography during the expansive reign of Philip II and the eclipse and reversal of secrecy policy through the ascension of Philip III and his reign of consolidation.
[8] Dear, Peter, *Revolutionizing the Sciences: European Knowledge and its Ambitions, 1500-1700*, 2nd Edition, 53.

facing the royal government, specifically its need to both constrain and disseminate this knowledge. Political and diplomatic desires for staking claims conflicted directly with the crown's desire to protect its monopolies and shield its shipping from the state sponsored piracy of its competitors. The need to inform ship pilots with the most up to date information invariably created a large system prone to leaks and theft. She examines the contradictions that existed between regulations and practice and concludes that this state of affairs reflected the uneasy balance reached between actors with conflicting state objectives.[9] The possibility also arises that sixteenth century Spanish navigational practice might have delayed the acceptance of heliocentric astronomy by hoarding information and selective dissemination.

Challenges to Aristotle, Ptolemy and Aquinas Reconciled

Despite the best efforts of the Iberian kingdoms, the new knowledge that their ships carried back from the world's oceans did not remain state secrets. As Kuhn observed,

> "Each new voyage disclosed new territory, new products, and new people. Men rapidly learned how wrong ancient descriptions of the earth could be. In particular, they learned how wrong Ptolemy could be, for Ptolemy had been the greatest geographer as well as the greatest astronomer and astrologer of antiquity. The astronomer's awareness … that Renaissance man could at last correct Ptolemy's geography prepared him for changes in his own closely related field."[10]

Gómez in his work examining the tropical motivations of Columbus, grounds Columbus in the scholastic epistemology of his day, but he contends that observation and discovery did not fundamentally undercut his Aristotelian worldview or his reliance upon Ptolemy's geocentric cosmography.[11] Despite evidence of major flaws in Ptolemy's geography, no viable alternative

[9] Sandman, Alison, "Controlling Knowledge: Navigation, Cartography, and Secrecy in the Early Modern Spanish Atlantic," chapter 1 in Delbourgo, James and Dew, Nicholas (editors), *Science and Empire in the Atlantic World.*
[10] Kuhn, 125.
[11] Gómez, 65, "Columbus is generally agreed to have culled his readings of ancient and medieval authors: his ideas about the globe's shpericity, which, incidentally were common in his day, his underestimation of the value of an equatorial degree and thus the globe's circumference; his overestimation of the eastward extension of Asia, which reduced the distance separating the Canary Islands from the end of the Orient; his contention that the torrid zone and

cosmological system offered a plausible replacement. Portuondo posits that the regal patronage undergirding Spanish cosmography led its adherents to develop a descriptive utilitarian science that catalogued and measured the natural world and the flood of information coming into Seville from the *carrera de Indias*. This project tactfully supported long distance oceanic trade and empire, but never challenged the Aristotelian natural philosophy embraced by medieval scholastics. New cosmographical data that ran contrary to classical texts was accepted, but the undergirding epistemology that produced those errors was not jettisoned – it left unchallenged the “philosophical underpinnings of Aristotelianism.”[12] This new Spanish science of cosmography, although sharing some empiricist, legalistic, and organizational characteristics with the Baconian method, did not seek causal reasons for the occurrence of natural phenomena. Spanish cosmography did not lead to modern science, even after it shed its cloak of secrecy, because it only sought to answer who, what, and where. It did not ask why. If the new world data was preparing European astronomers for major epistemological change, it was not doing so quickly.

Astronomers of the sixteenth century had read Copernicus, but as innovative as *de Revolutionibus* was, it earned few converts in its first five decades. The comment attributed to the Jesuit astronomer Christopher Clavius on the credible predictions made by using Copernicus' model are not atypical, “Copernicus simply showed that Ptolemy's arrangement was not the only

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the antipodes were inhabitable; and – one of the most debated aspects of Columbus's geography – the identity of the lands he intended to find.”

Lozano, 42, sees a more varied intellectual heritage noting that according to Columbus's son Fernando, “Strabo was one of Columbus' principal cosmographical authorities.”

Sanders, 44-45, disagrees on the circumference inference and offers evidence from the *Regimento do Astrolabio e do Quadrante*, the Portuguese manual from which Columbus derived a good deal of his training. Columbus and his contemporaries knew that a “degree of North-South [latitude] is 17½ leagues, and that sixty minutes make a degree.” He uses contemporary sources to derive a degree length of 6.5 km (by comparing the distance between the first and second demarcation lines of 1493 and 1494 respectively) and a pretty accurate earthly circumference of 40,000 km – his argument is that the globe being thought spherical, the circumference north-south would equal the distance around the equator and the distance between degrees of longitude at this largest point.

[12] Portuondo, 302.

way to do it."[13] Westman notes that the premier astronomer in Germany, if not Europe, Erasmus Reinhold was elated by the "Liberation from the equant! How much pride Copernicus had taken in this achievement; and Reinhold leaves no doubt that it was this accomplishment which had initially impressed him so deeply."[14] Copernicus was not rejected; he was just read judiciously and selectively.[15] Sixteenth century astronomers admired his mechanical solutions to astronomical problems as Owen Gingerich's survey of first and second edition marginalia attests:

> "But Reinhold and his many followers admired Copernicus for quite a different aesthetic idea, the elimination of the equant. … My Copernican census eventually helped to establish that the majority of sixteenth-century astronomers thought eliminating the equant was Copernicus' big achievement, because it satisfied the ancient aesthetic principle that eternal celestial motions should be uniform and circular or compounded of uniform and circular parts."[16]

However, despite the flood of data flowing into Iberia which contradicted Ptolemy and Aristotle, and their medieval scholastic interpreters, the sixteenth century would close with very few true Copernicans practicing astronomy.

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[13] Gingerich, Owen, *The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus*, 46.

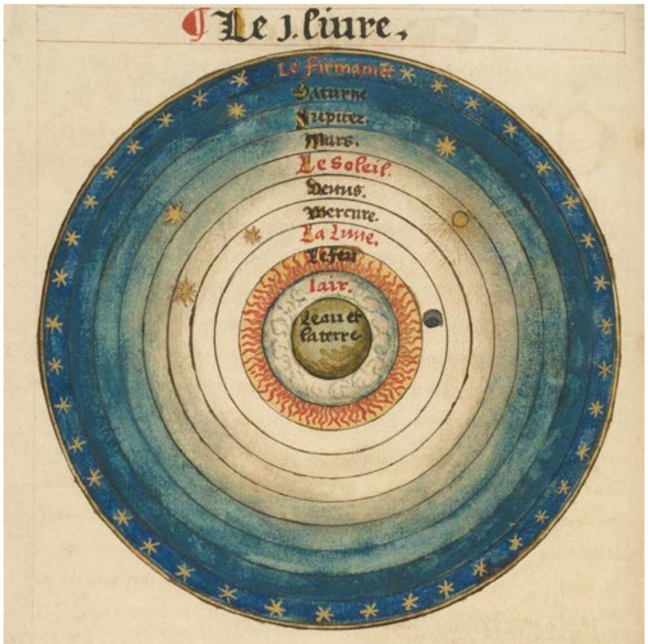
[14] Westman, Robert, "The Melanchthon Circle: Rheticus and the Wittenberg Interpretation of the Copernican Theory," 175.

https://en.wikipedia.org/wiki/Equant , "The equant (or *punctum aequans*) is a mathematical concept developed by Claudius Ptolemy in the 2nd century AD to account for the observed motion of the planets. The equant is used to explain the observed speed change in planetary orbit during different stages of the orbit. This planetary concept allowed Ptolemy to keep the theory of uniform circular motion alive by stating that the path of heavenly bodies was uniform around one point and circular around another point."

[15] Westman, "The Astronomer's Role," 106, "Typically what were adopted were those parts of the theory which did not depend upon the claim that the earth moves, namely, the theory of the precession of the equinoxes and planetary mechanisms constructed according to the principle that all motion in the heavens is both uniform and circular about the same center."

[16] Gingerich, 54-55.

* http://en.wikipedia.org/wiki/De_revolutionibus_orbium_coelestium, "Gingerich showed that nearly all the leading mathematicians and astronomers of the time owned and read the book; however, his analysis of the marginalia shows that they almost all ignored the cosmology at the beginning of the book and were only interested in Copernicus' new equant-free models of planetary motion in the later chapters."*



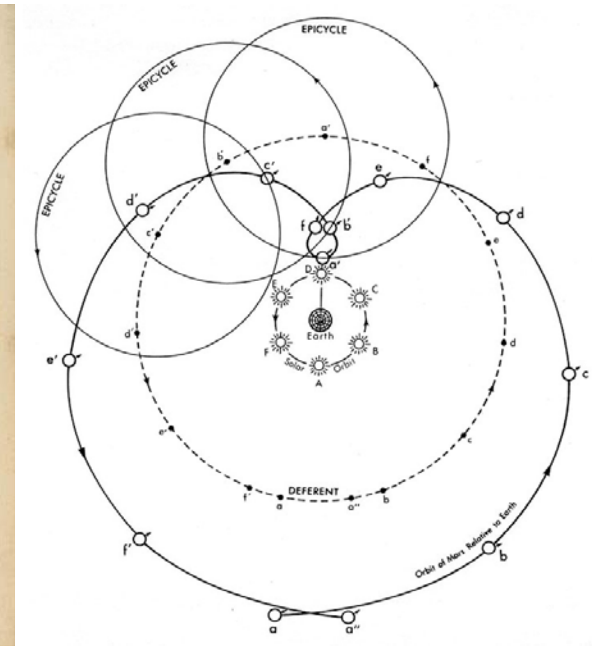
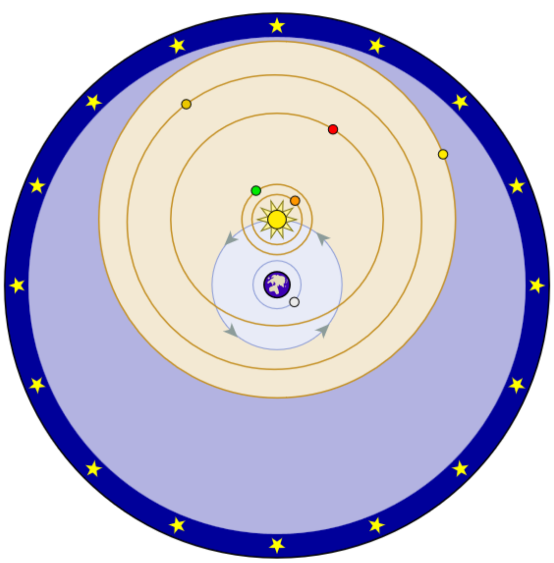


Figure 4.1. Geocentric (Ptolemaic) model of the universe and the Ptolemaic Epicycles. The French mathematician and cartographer Oronce Finé (1494-1555) placed a central Earth in his cosmos and the Sun between Venus and Mars. (http://jamreilly.tumblr.com/image/1580314663) In order to explain planet retrograde motion and the relative speed changes in planetary movement around the earth, the classical astronomers created the theory of planetary epicycles in their geocentric orbits to reconcile conflicting sensory data and the data that their model should have provided. The contortions required to make planetary movement 'fit' the model of a geocentric cosmos was laborious and involved a great deal of calculation, and was not entirely accurate. (https://web.njit.edu/~gary/202/Lecture3.html)



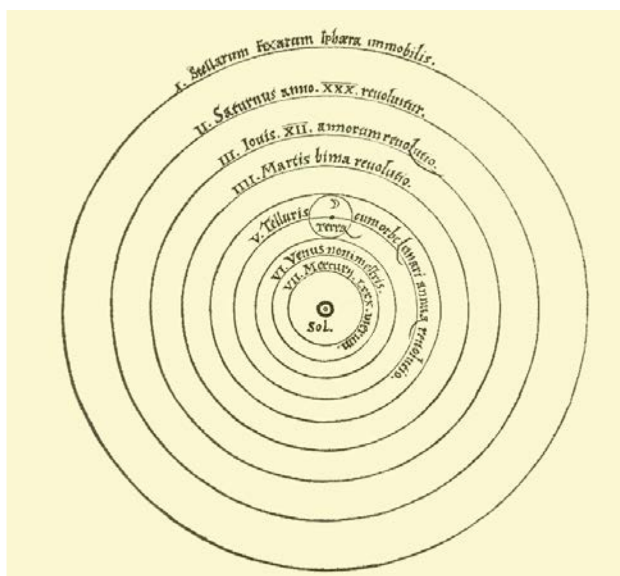


Figure 4.2. The Tychonian geocentric system and Copernicus' heliocentric cosmos . In Tycho's hybrid system only the Moon and the Sun and the fixed stars revolve around the Earth. The planets have a solar orbit. But, this system produces intersections that violate the sanctity of the heavenly spheres. (https://en.wikipedia.org/wiki/Geocentric_model#/media/File:Tychonian_system.svg) Copernicus centers the Sun, from Book I of *De revolutionibus orbium coelestium* (*On the Revolutions of the Heavenly Spheres*), 24. In descending order I. Immobile sphere of fixed stars; II. Saturn, 30 year revolution; III. Jupiter, 12 years; IV. Mars biannual; V. Earth annual; VI. Venus, 7½ months; and VII. Mercury in 88 days.

The New Astronomy and Sixteenth Century Astronomers

Of far greater concern to practicing sixteenth century astronomers than navigation was the calendar. Kuhn notes that

> "Agitation for calendar reform had an even more direct and dramatic effect on the practice of Renaissance astronomy, for the study of calendars brought the astronomer face to face with the inadequacy of existing computational techniques. … Reform in the calendar demanded, said Copernicus, reform in astronomy. The preface of his *De Revolutionibus* closed with the suggestion that his new theory might make a new calendar possible. The Gregorian calendar, first adopted in 1582, was in fact based upon computations that made use of Copernicus' work." [17]

Stellar shift and the 26,000 year cycle generated by the tilt in the earth's axis generate a slow cyclical rotation of the stars referenced from earth (precession) which over large amounts of time throw even the cleverest calendar out of sync with the seasons if not properly adjusted. The Julian calendar, built on Hellenistic Egyptian astronomy for Julius Caesar, was badly out of sync by the late middle ages. Again, Kuhn, "In Copernicus' day an adequate account of precession was the principal prerequisite for the most pressing problem of practical astronomy, the reform of the Julian calendar."[18] This far more obvious and daily evidence of the weaknesses of the old model, combined with new information and an appreciation of Copernican mathematics, over the years had a wearing effect on the once firm Ptolemaic consensus.

In addition, Kuhn posits that concurrent social upheaval makes paradigm shifts more acceptable. The sixteenth century Moslem resurgence, birth of nation-states (decline of feudalism), emergence of a commercial aristocracy, Protestant Reformation, technological development, strident anti-Aristotelian humanism, and ascendant Neo-Platonism all helped set the stage for acceptance of a new cosmology undergirded by a new physics. [19] But the

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[17] Kuhn, 125-126.
[18] Ibid, 271.
[19] Ibid, 124-129.

proponents of this new cosmology would need to both complete the system Copernicus had outlined and prepare to battle the defenders of the status quo.

Heliocentric Cosmos – Mathematical Model versus Physical Reality

Even though a universe centered on the sun and not on the earth struck the common and learned alike as counterintuitive and stubbornly obdurate to the data produced by one's own senses, it was not a novel idea in antiquity. Copernicus himself noted the Greek antecedents of his theory, noting that at least regarding the axially rotating earth, "the Pythagoreans Herakleides and Ekphantus were of this opinion and so was Hicetas the Syracusan in Cicero; they made the Earth to revolve at the center of the world."[20] Even though he does not mention Aristarchus of Samos, the first recorded theoretician to place the Earth in orbit specifically around the Sun, he does allude to possible Greek paternity of this central point,

> "And so it would not be very surprising if someone attributed some other movement to the earth in addition to the daily revolution. As a matter of fact, Philolaus the Pythagorean … is supposed to have held that the Earth moved in a circle and wandered in some other movements and was one of the planets."[21]

However, it is important to note, that the solar orbiting Earth of Copernicus' cosmos was not the only great heresy he presented. Copernicus' Earth rotated on its axis; this movement also contradicted the received wisdom of Earth as the stable fixed center off God's creation. As we shall see, some early supporters like William Gilbert were more comfortable openly supporting this lesser heresy, while remaining less definitive about the solar centered cosmos.

Kuhn gives a ready explanation how Copernicanism survived long enough to eventually triumph. "For those battles Copernicus had constructed an almost ideal weapon. He had made

[20] Copernicus, Nicolaus, *On the Revolutions of Heavenly Spheres*, 13.
[21] Ibid. Copernicus notes that Philolaus [of Croton] was a mathematician held in high regard by Plato. He speaks of a central fire about which the earth travels around. Aristarchus of Samos identified this fire with the Sun and correctly ordered the known planets in increasing concentric orbits.

the book unreadable to all but the erudite astronomers of his day. … By the time large-scale lay and clerical opposition developed, most of the best European astronomers, to whom the book was directed, had found one or another of Copernicus' mathematical techniques indispensable."[22] Westman offers a more nuanced explanation that the general acceptance of the diffusion of the Wittenberg Interpretation of Copernicus ("as the *reformer* of Ptolemaic astronomy") prevented early backlash against his thesis or the need for individuals to hide their views on his cosmology; "crypto-Copernicanism, the holding of secret Copernican convictions, was a phenomenon of the seventeenth century, rather than the sixteenth."[23] The university astronomers of Germany and elsewhere read the text for its mechanical merit, ignoring the central cosmological assertions they found implausible. [24]

The Wittenberg interpretation was a product of the 'Melanchthon Circle' as described by Westman.[25] Philipp Melanchthon permitted a partial acceptance of Copernican astronomy, but as a predictive tool, not cosmological reality. As an active member in the humanist movement, he dismissed the heliocentric thesis as "an old and absurd 'paradox' which Aristarchus had once

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[22] Kuhn, 185-186, although inaccessible to lay readers, he notes that "From the start the *De Revolutionibus* was widely read, but in spite of, rather than because of, it's strange cosmographical hypothesis."

Gingerich, 20, buttresses this assertion, "the first 5 percent dealt with the new Sun-centered cosmology … the other 95 percent was deadly technical."

[23] Westman, "The Melanchthon Circle," 181. Also see pgs. 191-192, Westman rejects Drake's indictment of medieval university as closed to new ideas and Kuhn's theory of a revolutionary paradigm choice not even fully supported by Copernicus, for a transitional 'cherry picking' of ideas that improved upon, rather than shattered the prevailing world view. Rather, Westman sees an evolving paradigm; one needing Kepler, Galileo, and Descartes to reach its fruition.

[24] Westman, "The Astronomer's Role," 106-107, "… one can justly term this initial reaction conservative, but certainly not reactionary." This caution was driven more by the subordinate position of astronomy and mathematics vis-à-vis philosophy in the medieval university hierarchy. Prediction was possible, but not so assertions of reality – as noted in Andreas Osiander's anonymous preface.

[25] Westman, "The Melanchthon Circle," 167, analogous to rising Italian academies of the fifteenth century – "a patron with a surrounding circle of intellectuals or a charismatic intellectual about whom gathered a group of scholars." Melanchthon represents the latter.

defended and which young students should stay away from since it conflicted with Scripture." However, among the senior students he encouraged debate and comparison.[26]

Even after the publication of Rheticus' *Narratio prima*, his associates focused their interest on Copernicus' impact upon the calendar, precession, and abandonment of equants. "None of Rheticus' Wittenberg colleagues had been struck by this deeper vision [heliocentric reality] of the universe."[27] But as alluded to by both Kuhn and Westman, the growing use of and reliance upon Copernicus' mathematics by practicing astronomers ensured that his book was both read and safe from obscurity. Westman notes, that "It is an interesting irony that, apart from Rheticus, those who did *not* accept the theory as true description of reality did more to articulate its mathematical structure than those who did accept it."[28]

Astronomers from Craftsmen to Natural Philosophers

New navigational data and an astronomer's appreciation of elegant mathematics did not quickly change the philosophical worldview because the knowledge provided by both of these users was subordinate to the knowledge of philosophers and theologians. Especially at the university, mathematics and astronomy were clearly subordinate to philosophy, theology, medicine, and law. John Henry notes that "the astronomer had to reconcile the putative mathematical structures, which provided him with his means of calculating planetary and other

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[26] Westman, "The Melanchthon Circle," 166, 169, 173-174. Melanchthon's educational reforms made Germany "the nursery of mathematics," according to Peter Ramus (French educational reformer). As a result astronomy was in a more advanced state in Germany in the 16th century "when compared with England, France, and perhaps even Italy." (172)

[27] Ibid, 185.

[28] Ibid, 190.

Spread by:	George Joachim Rheticus	'first disciple' in his *Narratio Prima*	
	Thomas Digges (English)	astronomer	1576
	Michael Maestlin (Kepler)	professor astronomy at Univ. Tübingen	
	Johannes Kepler	collaborator 65 years later	
Non-converts also spread the work for its mathematical efficacy:			
	Andreas Osiander	Lutheran theologian	anonymous preface
	Erasmus Reinhold	1551 – *Prutenic Tables*	
	Tycho Brahe	precision data, alternative hypothesis	

heavenly movements, with the demands of Aristotelian cosmology and physics."[29] He was not invited to criticize the physics. His station was clearly delineated by his salary, which fell well below professors of the loftier subjects.[30] Astronomers provided physicians and philosophers a service role as Westman states:

> "What counted as an 'improvement' in astronomy, then, usually meant some practical contribution: progress in its ability to make better predictions for the astrological physician, adjustments in the principles of the calendar, improved books on how to construct and operate well known instruments of observation, treatises on the computation of latitude and longitude at sea, or rationalization of astronomical pedagogy through better organized and more clearly educated textbooks."[31]

Mario Biagioli astutely observes in the case of Galileo "that he could teach in a university without a university degree [which] suggests that mathematics was perceived as a technical rather than a philosophical discipline, one that was learned through apprenticeship rather than formal university training."[32]

So, along with the battle for a new cosmology, and the inundation of new world data that discredited the epistemological pillars of the old order, there was also a class struggle in play. Both within intellectual circles and between institutions, Renaissance Europe was involved in an attempt to reorder hierarchies. To complete the comment from Wilding cited above,

> "Despite the fact that only around a dozen intellectuals might safely be identified as 'Copernicans' in the period before 1616, Protestants and Catholics alike suggested a wide range of proposals in order to establish the true nature of the hierarchy between the disciplines and their practitioners."[33]

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[29] Henry, John, *The Scientific Revolution and the Origins of Modern Science*, 9.
[30] Westman, "The Astronomer's Role," 119, "At Wittenberg and Marburg, for example, a professor of medicine could earn twice as much as a professor of mathematics."

Biagioli, *Galileo Courtier*, 7, contends that in Galileo's Italy mathematics salaries "did not confer must status on its professors, who in fact made between one-sixth and one-eighth the salary of philosophers." He cites his own "Social Status of Italian Mathematicians," pg. 53, in support.
[31] Westman, "The Astronomer's Role," 120.
[32] Biagioli, Mario, *Galileo Courtier: The Practice of Science in the Culture of Absolutism*, 7.
[33] Wilding, Nick, "Manuscripts in Motion: The Diffusion of Galilean Copernicanism," 223.

Westman claims that Copernicus' transgression was both epistemological and social. He made metaphysical claims about the nature of the universe (which he could not prove), using a mathematical tool (geometry) suited for predication and not metaphysical statements of being. Lastly, he "transgressed a disciplinary boundary." Westman believes that Copernicus, like Galileo in the following century, was trying to "assert a new relationship between mathematics and natural philosophy."[34] Although stymied in the universities at the time, these attempts were not altogether unfruitful. A change in venue and the evolution of a new institution (the princely court) would provide for what Westman describes as "a major change in both the intellectual and social role of the astronomer. [Since] Copernicus asserts implicitly the right of the astronomer to make new kinds of claims about the physical world."[35] New freedom allowed these astronomers to abandon philosophical propositions like solid spheres and the immutability of the heavens.[36]

Court Astronomers

Westman, Biagioli, and others chronicle the ascendency of the sixteenth century mathematician and astronomer from the medieval university's second tier to ascendency as socially equal natural philosophers in their own right and drivers of the Scientific Revolution, through venue and social changes derived from patronage strategies and emerging courtly culture. This opportunity was promulgated by the rise of a new user group for the wares of astronomers – courts.[37] This period marks the ascendancy of mathematics in academia and in the practical world.[38]

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[34] Westman, "The Astronomer's Role," 108.
[35] Ibid, 111.
[36] Ibid, 114-115, exploring Noel Swerdlow's proposition. Westman offers a different hypothesis on Copernicus' silence on the composition of spheres which is centered on the flaw spheres cast upon his theory's coherence. "Copernicus is seeking to avoid controversy and therefore [is] sidestepping direct mention of the materiality of spheres."
[37] Ibid, 122.
[38] Henry, 11, and Ash.

Biagioli has argued that Galileo choose the Medici court over the Padua University to "circumvent the disciplinary hierarchy characteristic of the university, a hierarchy in which mathematicians were subordinated to philosophers in terms of both professional status and salary."[39] For Biagioli, Galileo's pursuit of the court was for a *social instrument* essential to gain status to argue for the Copernican theory (heliocentric universe) and for the primacy of mathematics in natural philosophy. This institution had a determinative influence on growth of new science: "the court contributed to the cognitive legitimation of the new science by providing venues for the social legitimation of its practitioners, and this, in turn, boosted the epistemological status of their discipline."[40] Another court astronomer, not in Italy, but in Denmark, would provide the next step in the evolution of the Copernican model.

Tycho Brahe, Johannes Kepler and the New Copernicanism

Tycho Brahe, states Kuhn, was the best astronomer of the sixteenth century. "Trustworthy, extensive, and up-to-date data are Brahe's primary contribution to the solution to the problem of the planets."[41] However Brahe was not a Copernican, the issue of lack of stellar parallax was a 'deal killer' for Brahe, since it would imply an enormous stellar distance from the sun that was unacceptable to him. However Brahe did abandon critical Aristotelian elements (crystal spheres, the immutability of the heavens) which helped undermine the Aristotelian cosmography in favor of Copernicus.[42] Waters also notes the critical importance of Tycho Brahe's accurate observations, but he "condemned the Copernican system formulating one of his

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[39] Biagioli, Mario, "Galileo Emblem-Maker," 231.
[40] Biagioli, Mario, *Galileo Courtier: The Practice of Science in the Culture of Absolutism*, 2. See also pg. 6, Biagioli traces the transition of locus of continental scientific revolution from the "university, to the court, and, eventually, to the scientific academy." Galileo's career is again an exemplar. "After being a university mathematician, he became a natural philosopher at a court and then a member of what is often considered the first scientific academy – the *Accademia dei Lincei*."
[41] Kuhn, 201.
[42] Ibid, 206.

own which attempted to reconcile the Copernican and Ptolemaic theories, and which was often reproduced in navigation manuals of the later seventeenth century."[43] Regardless, the tables Brahe produced in 1600 were indispensable to mariners and their cosmopolitan sponsors as they were used to "build up an increasingly long table of astronomically determined longitudes" and to produce better solar declination tables, to more precisely track moon phases, and to track tide shifts.[44] Even though Brahe's observations were critical to navigators, their real significance was manifested in the work of Johannes Kepler.

By 1609, Kepler had completed the Copernican cosmography by using Tycho Brahe's observational data. After laboriously matching Brahe's data to myriad geometric forms over years, he introduced elliptical orbits and varying planetary speeds relative to orbital location. Kuhn contends that his Neo-Platonism disciplined his decade long hunt for an acceptably clean mathematical solution which scrupulously fit Brahe's data. "The Copernican astronomical system inherited by modern science is, therefore, a joint product of Kepler and Copernicus."[45] Both the original system of heliocentric orbits and Kepler's update with his laws of planetary motion had almost immediate consequence for mariners. Ever since the Portuguese started 'running down the altitude' in the fifteenth century, accurate ephemerides or astronomical tables identifying solar and stellar position on a given day with declination, became the essential building blocks of the declination tables built for ship's pilots by metropolis cosmographers. Increased accuracy in these tables translated directly into saved ships, cargo, and crew.

[43] Waters, 297.
[44] Taylor, *Haven Finding*, 226.
[45] Kuhn, 212-216.

Creation of the *Prutenic* and *Rudolphine Tables, and Magnetism*

In 1551, Reinhold issued a complete new set of astronomical tables, to replace the antiquated *Alfonsine Tables* assembled in Castile in the thirteenth century, "computed by the mathematical methods developed by Copernicus, these soon became indispensable to astronomers and astrologers, whatever their beliefs about the position and motion of the earth."[46] Reinhold's *Prutenic (Prussian) Tables* were the "first complete tables prepared in Europe for three centuries." Kuhn suggests that "Every man who used the *Prutenic Tables* was at least acquiescing in an implicit Copernicanism."[47] "Reinhold's *Prutenic Tables*, based on Copernicus's mathematical system, were used in the reformation of the calendar promulgated for the Catholic world in 1582 by Gregory XIII" by Christopher Clavius, the Jesuit astronomer of the college of Rome.[48]

However, with the exception of the calendar reform, these tables did not disseminate much outside Germanic central Europe. Only Kepler's *Rudophine Tables* would gain continental ascendancy when they were published in 1627. Reinhold's tables, based upon Copernicus' circular orbits and the resultant need for epicycles (even though Copernicus had shed the need for Ptolemy's epicenters, he could not account for observational discrepancies without this Ptolemaic device), while clearly superior to their Alfonsine predecessor, could not match the accuracy of Kepler's elliptical orbits. Even though it would take Newton's physics of gravity to fully account for passing planetary distortions within elliptical orbits, these tables were markedly more accurate than anything that had preceded them. [49]

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[46] Kuhn, 187.
[47] Ibid, 188.
[48] Ibid, 196, and Gingerich, 22.
[49] Kuhn, 219, "Kepler solved the problem of the planets … particularly after 1627 when Kepler issued the *Rudolphine Tables*, derived from his new theory and clearly superior to all the astronomical tables in use before."

As useful as these new tools were to navigation, it is important to stress that Kepler's work was heavily influenced by the work of the Englishman William Gilbert. Henry notes that "Johannes Kepler adapted Gilbert's in his physicalist *New Astronomy* (1609), explaining the motions of the planets around the sun by recourse to something like magnetic force."[50] After rejecting Ptolemy's planetary spheres, Kepler searched for a mobile force to explain the elliptical motion of his orbiting planets. He imagined a stellar force (*anima motrix*) projecting out of a rotating sun. These rays propelled the planets around in a circular orbit. However, Kepler needed a second force to create an elliptical path – this force he identified as magnetism. He derived his ideas from William Gilbert's 1600 treatise *De Magnete (On the Magnet)*. "Gilbert had recognized that the earth itself was a huge magnet, and Kepler extended the generalization to the other bodies of the solar system."[51]

Taylor states that "Gilbert boldly accepted the Copernican doctrine of terrestrial rotation, and thence proceeded to the theory that the earth itself was a rotating magnet."[52] Although Peter Dear is quick to caveat that Gilbert was willing to accept Copernican earthly rotation about "its own axis if not around the Sun – he was cagey about the latter point."[53] Gilbert's track was widely read and was even cited by Galileo in his 1615 reply to Cardinal Bellarmine.[54] Galileo also explicitly accepted the earth's axial rotation publicly before the publication of his *Dialogue* in his Letter to the Grand Duchess Christina of 1615; beginning with Proverbs 8:26, "'He had not yet made the earth, nor the rivers, nor the poles of the terrestrial globe,' one could understand in poles literally; for there would be no point in attributing these poles to the terrestrial globe if it

Mosely, Adam, Department of History and Philosophy of Science of the University of Cambridge, 1999, http://www.hps.cam.ac.uk/starry/tychotables.html , "Although it was not immediately recognized, the positions predicted in this work were generally around thirty times better than those of previous and competing tables."

[50] Henry, 49.

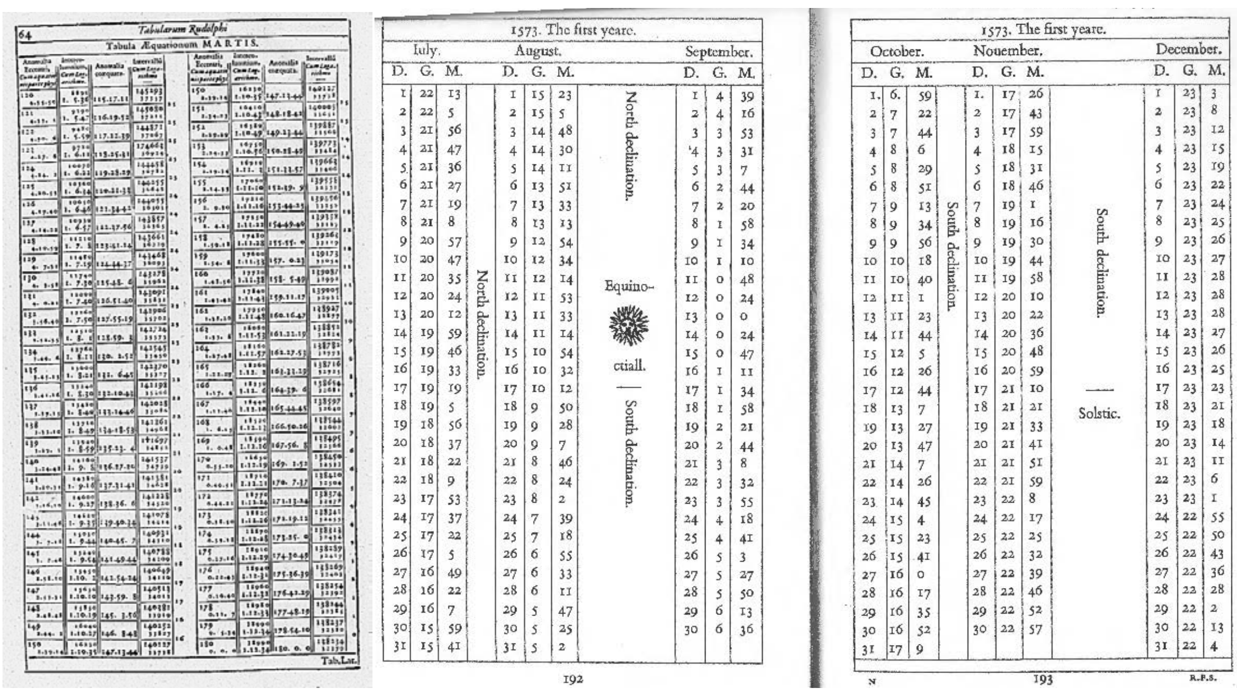
[51] Kuhn, 224.

[52] Taylor, E.G.R., *Late Tudor and Early Stuart Geography 1583-1650*, 69.

[53] Dear, 53, Gilbert on magnetism – In his *De magnete* (On the Magnet), published in 1600.

[54] Finocchiaro, Maurice, *The Essential Galileo*, 150.

did not have to turn around them."[55] This was not an earth in motion around the sun, but spinning was motion none-the-less. Taylor also notes that "Gilbert's researches upon magnets and magnetic bodies were begun about 1582. … Although the author's main purpose was the elucidation of the true nature of electricity and magnetism, he devotes his final chapters to those practical problems of navigation in which so many of his friends, including [Edward] Wright, were interested."[56] The Copernican hypothesis had made a full circle – its end product of improved declination tables were being used by navigators, and as we shall explore further in Chapter 6, their demands for better tools (in this case a resolution to magnetic compass variation and dip) were in part promulgating theories which were shaping the new Kepler engineered Copernicanism.



1573. The first yeare.

Iuly. D.	G.	M.	August. D.	G.	M.	September. D.	G.	M.
1	22	13	1	15	23	1	4	39
2	22	5	2	15	5	2	4	16
3	21	56	3	14	48	3	3	53
4	21	47	4	14	30	4	3	31
5	21	36	5	14	11	5	3	7
6	21	27	6	13	51	6	2	44
7	21	19	7	13	33	7	2	20
8	21	8	8	13	13	8	1	58
9	20	57	9	12	54	9	1	34
10	20	47	10	12	34	10	1	10
11	20	35	11	12	14	11	0	48
12	20	24	12	11	53	12	0	24
13	20	12	13	11	33	13	0	0
14	19	59	14	11	14	14	0	24
15	19	46	15	10	54	15	0	47
16	19	33	16	10	32	16	1	11
17	19	19	17	10	12	17	1	34
18	19	5	18	9	50	18	1	58
19	18	56	19	9	28	19	2	21
20	18	37	20	9	7	20	2	44
21	18	22	21	8	46	21	3	8
22	18	9	22	8	24	22	3	32
23	17	53	23	8	2	23	3	55
24	17	37	24	7	39	24	4	18
25	17	22	25	7	18	25	4	41
26	17	5	26	6	55	26	5	3
27	16	49	27	6	33	27	5	27
28	16	22	28	6	11	28	5	50
29	16	7	29	5	47	29	6	13
30	15	59	30	5	25	30	6	36
31	15	41	31	5	2			

North declination. North declination. Equinoctiall. South declination.

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1573. The first yeare.

October. D.	G.	M.	Nouember. D.	G.	M.	December. D.	G.	M.
1.	6.	59	1.	17	26	1	23	3
2	7	22	2	17	43	2	23	8
3	7	44	3	17	59	3	23	12
4	8	6	4	18	15	4	23	15
5	8	29	5	18	31	5	23	19
6	8	51	6	18	46	6	23	22
7	9	13	7	19	1	7	23	24
8	9	34	8	19	16	8	23	25
9	9	56	9	19	30	9	23	26
10	10	18	10	19	44	10	23	27
11	10	40	11	19	58	11	23	28
12	11	1	12	20	10	12	23	28
13	11	23	13	20	22	13	23	28
14	11	44	14	20	36	14	23	27
15	12	5	15	20	48	15	23	26
16	12	26	16	20	59	16	23	25
17	12	44	17	21	10	17	23	23
18	13	7	18	21	21	18	23	21
19	13	27	19	21	33	19	23	18
20	13	47	20	21	41	20	23	14
21	14	7	21	21	51	21	23	11
22	14	26	22	21	59	22	23	6
23	14	45	23	22	8	23	23	1
24	15	4	24	22	17	24	22	55
25	15	23	25	22	25	25	22	50
26	15	41	26	22	32	26	22	43
27	16	0	27	22	39	27	22	36
28	16	17	28	22	46	28	22	28
29	16	35	29	22	52	29	22	2
30	16	52	30	22	57	30	22	13
31	17	9				31	22	4

South declination. South declination. Solstic.

N 193 R.F.S.

Figure 4.3. Kepler's Rudolphine Tables and Bourne's Declination Tables. Kepler's tables were 30 times more accurate than their European or Arabic predecessors. Cambridge's Professor Sachiko Kusukawa notes that "its margin of error staying within 10 seconds compared to up to 5 degrees with earlier tables. Instead of providing a sequence of planetary positions for specified days (which Kepler did in his Ephemerides), the Rudolphine Tables

[55] Finocchiaro, 145.
[56] Taylor, *Late Tudor and Early Stuart Geography*, 68-69.

were set up to allow calculations of planetary positions for any time in the past or future."[57] Kepler exploited logarithms to fix planetary longitude based, not upon Brahe's observational data, but rather upon the elliptical solar orbits which his long analysis of that data suggested. The Navigational Declination Tables from William Bourne's *A Regiment for the Sea* published in 1574 (right) , like their Portuguese and Spanish predecessors in the *Regimento do Astrolabio e do Quadrante* and Martín Cortés' *The Arte de navigar* respectively, predated the accuracy advances provided by Kepler's Rudolphine Tables, but unlike the Portuguese tables built upon the thirteenth century Alfonsine Tables, these, like Cortés' were built upon the Copernican mathematical advances which Reinhold built into his 1551 Prutenic (Prussian) Tables. [58]

The early Iberian navigators unknowingly had benefited from the axial rotation that Gilbert and Galileo so freely embraced, but they had noticed the result of this rotation. The *volta do mar* was a discovery of the atmospheric and hydrologic oceanic rotation driven by the trade winds and the earth's rotation. The North Atlantic Gyre – necessary for Prince Henry's sailors return features a clockwise rotation of current and wind off shore. In the South Atlantic, the South Atlantic Gyre rotates counter-clockwise and required a westerly course to almost Brazil for outbound Indiamen.[59] The doldrums or calms center on the Equator. Similar gyres exist in the Pacific and were essential for Spain's Philippine Galleon. The Portuguese discovered and exploited the atmospheric and hydrological byproducts of this rotational effect, but did not discover its cause. That this rotation was identified by an Englishman in regards to another effect (terrestrial magnetism) at the dawn of the seventeenth century is indicative of were the leading edge in navigation research was moving – and that was north. Even though the Iberian powers had a long experience with managing the inflow of new cosmographical data, Taylor points out that,

[57] Kusukawa, Sachiko, Department of History and Philosophy of Science of the University of Cambridge, 1999, "Kepler and Astronomical Tables," Sites.hps.cam.ac.uk, http://www.hps.cam.ac.uk/starry/keplertables.html.
[58] Bourne, William, *A Regiment for the Sea and Other Writings on Navigation By William Bourne of Gravesend, a Gunner (c.1535-1582)*, edited by E.G.R. Taylor, 192-193.
[59] Law, "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," 118-119, defeating Cape Bojador – the point of no return – required three types of technological innovation:

(1) mixed-rigged sea going vessel – ability to convert multiple wind conditions and survivable, sails for power reduced crew and increased cargo room – 14th and early 15th centuries

(2) magnetic compass – freed sailors from coast hugging

(3) sailing out to sea to obtain more favorable winds to return home – "It was the invention of this circle, called the *volta* by the Portuguese, that marks the decisive third step."

> "In Spain and Portugal navigation to the Indies had settled down into a fixed routine, but in Elizabethan England men's minds were full of projects for colonization, discovery and naval warfare. And some of them at least realized that the necessary improvement of methods was at base a mathematics problem."[60]

The largely protestant north was no more enamored with Copernicus' heresy than Rome was, but the climate there was different and change came at a different pace.

The Ascendency of the Copernican Model, Mathematics and Astronomy

Kepler's reconciliation of Brahe's data and Copernican theory resulted in his laws of planetary motion. Waters contends that "Arising from these came forth in 1627 the *Rudolphine Tables* (Ephemerides) under Kepler's editorship. … It was the death-knell, as has been truly remarked, of the old astronomy. In England, indeed, the Copernican theory was pretty firmly established by the seventeenth century."[61] Even though Galileo's telescopic astronomy in 1609 added "the first qualitatively new sort of data that it [astronomy] had acquired since antiquity", the battle for heliocentric supremacy was already over.[62] Kuhn caveats his victory statement with, "The telescope did not prove the validity of Copernicus' conceptual scheme … it was not proof, but it was propaganda."[63] Sadly for Galileo, the battle was not over, but it is hard in hindsight to say that the writing was not on the wall. As for navigation, astronomical precision determined life and death at sea and in the seventeenth century cutting edge navigation was both influencing and influenced by Copernicus' heliocentric astronomy and Kepler's laws of planetary motion.

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[60] Taylor, *The Haven-Finding Art*, 215.
[61] Waters, 297.
[62] Kuhn, 219, 220-223, describes what was left a 'Mopping up operation' – telescopic data provided for heavenly immutability, immense star distances, planetary stellar orbits (Venus phases), planetary satellites like earth (Jovian moons), making it a perfect [if impractical] stellar clock based upon eclipse frequency.
Waters, 299, "Thus 1610 saw the old astronomy, already shaken the year before by Kepler's planetary laws, all but smashed by Galileo's published observations. Final proof of the validity of the Copernican theory – the actuality of stellar parallax – had to wait two centuries before instruments of sufficient power enabled it to be observed."
[63] Kuhn, 224.

Connections

Geocentric astronomy was good enough to launch the caravels, but it would not have served Captain Cook. Even though the slightly more reliable predictive ability of Copernicus' model was not elegant or refined enough to provide practicing sixteenth century astronomers a demonstrably better tool that would warrant jettisoning their existing Kuhnian paradigm, the quantitative differences produced by Kepler were demonstrative. Navigation science evolved with astronomy, at least since the Portuguese created navigational system that relied upon astronomical product was absorbed by her neighbors, but only once astronomy itself had absorbed, refined, and started processing its new paradigm. Westman's proposed intermediate paradigm is apt in this situation. The early stage of refinement of the Copernican system (during the second half of the sixteenth century) was an affair conducted by and for astronomers. This period coincided with a similar diffusion of astronomical navigation northward up Europe's Atlantic seaboard which created multiple navigational astronomical product users in the sixteenth century. At the convergence of these trends, early in the seventeenth century, communities interested in mathematical navigation and the new astronomy appear to have begun a far more complex and reciprocal relationship. This new astronomical product was both in part produced for and refined by navigators collecting data for metropolitan astronomers and tailored to the exigencies of their expanding oceanic reach. We will address this phenomenon in more detail in Chapters 5 and 6.

In retrospect, a novel theory was a critical factor in the continuing development of astronomical and mathematical navigation in late Tudor and Stewart England and elsewhere and the accomplishments of the Iberians and their competitors at sea buttressed the Copernicans in the long run, by undermining the old paradigm through their efforts and through their demands for more astronomical precision. As we shall see in Chapter 7, the emergence of mathematical navigation in the seventeenth century demanded better astronomy and the contribution of more innovative astronomical practioners most likely to embrace the new and more mathematically satisfying Copernican model. Kuhn notes that

> "Successful voyages demanded improved maps and navigation techniques, and these depended in part on increased knowledge of the heavens. Prince Henry the Navigator, organizer and director of the early Portuguese voyages, constructed one of the earliest European observatories. Exploration therefore helped to create a demand for expert European astronomy, and having done so, it partially changed their attitude toward their field."[64]

The relationships, exchanges, and debts between the Copernican astronomers and the great explorers were reciprocal.

But if the linkage between navigation and heliocentric astronomy was intertwined, how exactly does this impact our question regarding the impact of the maritime project and the fitful emergence of modernity? To make this connection, one must take sides in the Scientific Revolution as epistemological revolution versus the revisionist continuity debate. The traditional narrative of the Scientific Revolution starts with Copernicus, accelerates with Galileo and Descartes, jumps the channel to Bacon and the Royal Society, and reaches culmination with Sir Isaac Newton.[65] It is a story about astronomy, physics, and mathematics and the unseating of Aristotelian epistemology as defined by medieval scholastics. It is the herald and instigator of modernity. Alexandre Koyré added grandiosity to this narrative by declaring in the middle of the last century that the Scientific Revolution was not just the birth of quantitative empirical science, but that it initiated a fundamental epistemological change in Western Man and through European expansion, that of the modern world, "bringing forth the destruction of the Cosmos, that is, the

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[64] Kuhn, 125.
[65] Henry, 21, "Issac Newton's Mathematical Principles of Natural Philosophy (1687) can be seen as the culminating point of the mathematization of the world picture."

disappearance, from philosophically and scientifically valid concepts, of the conception of the world as a finite, closed, and hierarchally ordered whole."[66] It marked "the divorce of the world of value and the world of facts."[67] Early in the same century, the historian Herbert Butterfield went as far as to claim that the Scientific Revolution "outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes."[68] So the question arises, is this too much? Is it too little? Or just perhaps, is this view too narrow?

Ever since early modern Europeans jettisoned the Aristotelian epistemology that had governed thought in the West for millennia, we in the West have placed our faith in the objectivity of science and in the rationality of the scientific method. Francis Bacon, unsatisfied with the Aristotelian philosophic method which relied on deductive syllogisms to interpret nature, and which was prevalent among natural philosophers in sixteenth century Western Europe, penned a corrective to this approach in his seminal work, *Novum Organum.* Bacon's presented his 'New Instrument' or tool of analysis, 'the scientific method,' as one more efficient for uncovering objective truth in the natural world. His method, mandated 'objective' observation, embraced unanticipated outcomes, privileged the dispositive, and used inductive reasoning. The Baconian method has been the structural basis for Western science for four centuries and is thoroughly ingrained in our intellectual baggage, but at the turn of the seventeenth century, Bacon felt a need to 'sell' his approach as one superior to the prevalent Scholastic and Aristotelian approaches used by most medieval scholars.

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[66] Koyré, Alexandre, *From the Closed World to the Infinite Universe*, 8.

Shapin, Steven, *The Scientific Revolution*, "In 1943 the French historian Alexandre Koyré celebrated the conceptual changes at the heart of the Scientific Revolution as 'the most profound revolution achieved or suffered by the human mind' since Greek antiquity." The phrase 'Scientific Revolution' was not even common until Alexandre Koyré popularized it in 1939.

[67] Koyré, 9.

[68] Lindberg, David, "Conceptions of the Scientific Revolution from Bacon to Butterfield," 1.

Bacon's basic objection to the use of deductive logic as a method of natural inquiry rested on the reasonable observation that logic, no matter how flawless its application, cannot derive truth from erroneous presumptions.[69] Bacon delineated four categories of erroneous presumptions "besetting human minds." These 'Idols' were those of the Tribe, the Cave, the Market-place, and of the Theater.[70] Having categorized the different limitations in humans and their institutions involved in searching for truth in nature, Bacon presented his inductive method as a tool useful in dispelling subjective predispositions and for discovering 'objective truth'.

This method was spectacularly successful. The advances in European science since its adoption were without parallel in human history. Even when the fruits of scientific and technological advances, concomitant with the rise of capitalism, helped create the social dislocations that gave rise to sociology, science still was granted prestige. In the early twentieth century, Robert Merton did note the inherent conflicts that existed between science and different social institutions.[71] Merton posited that the beleaguered institution of science was characterized by four salient characteristics: (1) universalism, (2) communism [communally shared results], (3) disinteredness, and (4) organized skepticism.[72] These normative structures of science were not

[69] Bacon, Francis, *Novum Organum*, Aphorism I, 14, pg. 46.
[70] Bacon, Aphorism I, 39, pg. 53, the Idols of the Tribe are endemic to humanity itself and encumber us all with preconceived ideas and an innate desire to affirm what we think we know. Idols of the Cave (drawing on Plato's allegory) are particular to each individual. The individual's 'reality' is built from experience, education or affiliation and thereafter clouds objectivity and posits one's personal experience as the touchstone of truth. Idols of the Market-place concern words, the social freight they carry, and the trap engendered by the inadequacies and coercive directive imbued in language. Lastly, Idols of the Theater concern philosophical sects, superstitions, and the inappropriate mixing of natural philosophy (physical science) and theology. This last Idol leads to three problems: "Sophistical [logic predominates], Empirical [over generalizations run rampant], and Superstitious [were conflation of science and religion retards both]." (Aphorism I, 62, pg. 68)
[71] Merton, Robert, "Science and the Social Order," 328, noted that science could not prosper as a ward of the church, the economy or the state. Pg. 333, despite the wide variety of state structures which supported the early institutionalization of modern science, Merton posited that science had a distinct connection to social structures within a state and would function better if it was embedded within certain social structures rather than others. Regardless, Merton concludes that we had reached a point where social hostilities toward science existed in many societies, but that the prestige that science had gained by delivering material progress tempered assaults upon it.
[72] Merton, Robert, "Science and Technology in a Democratic Order," 115-126, Universalism holds that all truth claims must be verified by the same process and that ensuing knowledge be certified. This tenant demands open access to science and the acceptance of knowledge discoveries on scientific terms. The knowledge that scientists

subjected to serious critique until the wholesale postmodernist rejection of the enlightenment project began after the catastrophe of two world wars, the Great Depression, and the atomic bomb shattered the modern faith that science would lift humanity from its natural and self-inflicted agonies. This scientific apostasy is at the core of revisionist arguments that the Scientific Revolution was neither a temporal event, nor an objective and homogeneous project.

As we discussed in the Introduction, in the early 1960s Thomas Kuhn proposed a corrective to the linear and cumulative view of scientific progress that had lost so many adherents. Kuhn and philosophers of science rejected the Baconian principle that science revealed objective truth.[73] Instead, they viewed knowledge itself as a social construct, a thing to be produced to resolve temporal social problems. This acceptance of relativism in regards to scientific output invariably leads to a world were all scientific claims are suspect, no matter how sound the theory or replicable the predictions.[74]

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discover belongs to the scientific commons. For science to progress it must be cumulative, open and free from legal constraint. Recognition and possible naming rights become the focal rewards for scientific discovery. The institution prizes originality and grants esteem to those who emerge from a highly competitive process with something new. The disinterededness and organized skepticism of science also brings science into conflict with the societies in which it is embedded. Results must be verified and examined dispassionately and with vigor. Openness and a willingness to confront religious, economic and political groups are essential characteristics of the scientific project and a major source of social friction.

[73] Kuhn, Thomas, *The Structure of Scientific Revolutions,* In contrast to Francis Bacon, Kuhn contends that normal science and the progress its adherents make in identifying the workings of nature is dependent upon both the scientist's education and indoctrination into a paradigm (adopting Idols of the Cave) and upon the language and definitions provided by the field (absorbing and using Idols of the Market-place). Where Bacon wanted the scientist to recognize and isolate these and other idols, Kuhn insists that these preconditions provide the scientist with the *only* suitable tools for normal scientific work. Kuhn contends that normal science searches for confirmations of its paradigm, not for Bacon's objective facts or Popper's falsifications.

[74] Ibid, 172. Kuhn denies the charge that he is a relativist. He claims that this charge is levied because he rejects the teleological view of the march of scientific progress and rather believes in a Darwinian view of science as a march toward no specific goal other than "best available" temporal adaptation to current circumstance. He insists that we should judge a scientific system in the context of the questions it must answer (as in the case of Ptolemaic geocentric astronomy). He claims that the theories of newer science (i.e. Copernicus's heliocentric astronomy) are simply better suited to answering their own specific puzzles. However, he also contends (pg. 206) that newer science does not "approximate more and more closely to, the truth." [If so, how are the facts presented by a paradigm that posits the earth as the center of the universe any different than one in which the earth rotates around the sun? If observations are only to be judged within the context of their own paradigm, how is that anything but relativism?]

A variant of this analysis of scientific objectivity was introduced by adherents of the sociology of scientific knowledge (SSK) in the 1980s and 1990s. Steven Shapin, a historian and sociologist of science, established the importance of place, locality, and socially constructed trust mechanisms in the generating and creation of scientific knowledge. He proposed an admittedly relativist theory that examined the mechanisms by which certain knowledge is accepted as true. He also rejected the modernist view of objective truth as the product of scientific research as presented by Francis Bacon.[75] Rather, he recommended that the proper avenue for the historian is "to 'treat knowledge as what counts as knowledge' in various times and places, to 'treat truth as what counts as the products of truth-judgments' in various times and places."[76] Using this temporal and cultural framework, Shapin has examined the production of scientific knowledge in seventeenth-century England and drawn several applicable conclusions about truth claims. This led him to a dramatically revisionist view of the Scientific Revolution which he espoused in an eponymously titled book and which establishes one of the many 'Continuity' positions.

Steven Shapin starts his provocative book with the claim, "There is no such thing as the Scientific Revolution, and this is a book about it."[77] This tongue in cheek introduction is just that – Shapin does not set out to challenge the notion that there was a major epistemological and methodological change in the study of natural sciences in early modern Western Europe, that this change had profound influence on how Western man viewed his place in the cosmos, that it

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[75] Shapin, Steven, "Placing the View from Nowhere: Historical and Sociological Problems in the Location of Science," 5, Shapin rejects Durkheim's contention that scientific truth's "are independent of any local context" and presents the SSK argument to the contrary. In order to do this he must explain the ability of scientific discovery and methods to rapidly travel and transcend their originating culture. He partially accepts Bruno Latour's argument of 'domination, drilling and discipline,' but thinks it to be insufficient. Shapin adds his observations on the scientific reliance on trust to the argument, but he fails to explain why the local populace and other cultures would accept or trust in a science in the absence of the demonstrable reasonableness of its claims. If scientifically generated facts did not generate better technology or a more coherent understanding of the natural world how would they withstand long-term scrutiny? If modern biology did not produce theories of pathogens that resulted in the production of drugs that relieved misery or extended life, how would these social trust systems support these scientific facts?

[76] Shapin, Steven, "Rarely Pure and Never Simple: Talking About Truth," 2.

[77] Shapin, Steven, *The Scientific Revolution*, 1.

rejected the Aristotelian epistemology that had been predominate in Western Europe in the late Middle Ages, or that in its creation, we can see the birth of what we call modernity. Rather Shapin assaults the notion of a brilliant homogenous revolution without historical context.

Shapin states that, "there is ***no essence*** of the Scientific Revolution, a multiplicity of stories can legitimately be told, each aiming to draw attention to some real feature of that past culture."[78] He also wants to "draw attention to the ***cultural heterogeneity*** of seventeenth-century science." [79] In focusing his work on experimental philosophies, in lieu of physics, Shapin wants to illustrate the "attempts to 'mechanize' not only nature but the means of knowing about nature, as well as *conflicts* over the propriety of mechanical and experimental mode, do capture quite a lot that is worth understanding about cultural change in this period."[80] To Shapin, the Scientific Revolution was not an isolated event, separated from its past, executed by one distinct set of individuals of the same background and purpose, and was not confined to what today we call physics.

However, the ephemeral change in how we view the natural world and the introduction (in some quarters – primarily England) of a regimented dispassionate method by a small group of Western European gentlemen, did radically alter the prevailing epistemology of Western Christendom and eventually has become the basis of modern global science. Steven Shapin and Simon Schaffer present *Leviathan and the Air Pump* as both "a large-scale *instantiation* of what the sociology of [scientific] knowledge [SSK] might look like … that is to say, … a case study,"[81] and as an examination of seventeenth century natural-philosophy in Restoration England. Noting first the well-established history of using the case study model in history of

[78] Shapin, *The Scientific Revolution*, 10.
[79] Ibid, 11.
[80] Ibid, 12.
[81] Shapin, Steven and Simon Schaffer, *Leviathan and the Air Pump*, xl-xli.

science studies (Conant, Kuhn); the authors do note its weaknesses – localized, temporal and specific – as a tool for generating broad conclusions. Despite these reservations, in their examination of the particular debates between the Royal Society experimental exemplar Robert Boyle and the political philosopher Thomas Hobbes, the authors are confident to make the assertion that "Solutions to the problem of knowledge are solutions to the problem of social order."[82]

Shapin and Schaffer are concerned with the 'rules of the game' and how these came to be established in the sociological truth verification regime of early modern English science. Their book is a methodological study. The authors focus on the contest within the heterogeneous community of the time – theirs is a story of contest and the battle for methodological ascendency.[83] It specifically rejects a uniform essence or spirit of inquiry for the period. The legitimate question raised is; has the march from the scientific method towards and past postmodernism taken us full circle toward the acatalepsy Bacon so fiercely resisted in *Novum Organum* as we deny the existence of objective truth and insist everything is socially constructed or relative?[84] However, we will leave this question and focus on commonalities.

Revolutionists and continuity advocates adhering to Shapin both admit an early modern European dramatic change in epistemology, the human place in the universe, and the proper method for generating knowledge about the natural world, but quibble over the existence of a

[82] Shapin and Schaffer, 332.
[83] Ibid, xliv**,** "… heterogeneity they found; they saw it as a normal, and arguably a pervasive, feature of science-in-the-making. … the absence of reference to a coherent 'essence' of seventeenth-century science, of what it meant to be 'modern,' of the 'Scientific Revolution.'"
[84] Bacon, Francis, "Aphorisms Concerning the Interpretation of Nature and the Kingdom of Man," *Novum Organum*, (1620), translated and edited by Peter Urbach and John Gibson (Chicago: Open Court), Extracts, Aphorism I, 37, pg. 53. Bacon notes that his "method and the reasoning of those who held the doctrine of Acatalepsy [that knowledge of anything is impossible] are somewhat similar in the initial stages, but in their outcome are very far apart, and indeed opposed. While they roundly assert that nothing can be known, I say we cannot know much of Nature through the means now in use. While they proceed to destroy the authority of the sense and understanding, I devise and furnish ways of helping them."

coherent early modern 'essence' and the heterogeneity of the key actors. More extreme continuity advocates deny any break with the evolving practices of the High Middle Ages and Renaissance and find evidence of empiricism in occult trades like alchemy and in the 'vulgar' professions of midwives and apothecaries.[85] Regardless of its factual merits, John Henry notes that "Continuism can be seen, however, at least to some extent, as an antidote to Whiggish tendencies because it tends to be backward-looking, rather than inherently forward-looking."[86]

Whether one accepts the 'Scientific Continuity' rejection of the Scientific Revolution or not; there is a great deal to be said for broadening the sources, locations, and actors of this early modern drama. Pamela Smith may overstate the case when she asserts that, "Moreover, while changes in the theories of the cosmos are, of course, exceedingly important in the long run, in the period 1450 to at least 1650, I believe the real story lies in changing attitudes to nature, to natural knowledge, and to knowledge making."[87] I tend to disagree with this statement only in degree. I do not award these developments the determinative role as the impetus for both method and epistemological change assigned to them by their advocates as being greater or even equal to the astronomical and physics influences. But as the Aristotelian world view (at least as espoused by its Scholastic heirs) was comprehensive regarding philosophy, metaphysics, natural philosophy, and natural history; it is very understandable that its new competing replacement view would need to encompass and receive impetus from myriad sources.

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[85] Smith, Pamela H., "Science on the Move: Recent Trends in the History of Early Modern Science," *Renaissance Quarterly;* **62:2** (Summer 2009), 353, 356-357.

Eamon, William, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture,* 5, Eamon makes one such continuity argument on behalf of medieval books of secrets. He examines books of secrets published in the sixteenth century in Western Europe and makes the case that herein were the roots of the Scientific Revolution. He notes that these books carried on the esoteric and revelation based philosophy of late antiquity and appealed to the reverence for ancient authority of a recovering medieval world. They appealed to Renaissance thinkers searching for original wisdom and to those looking for material advantage. However, Eamon contends that even though "the Scientific Revolution exposed and neutralized nature's 'secrets'", that these books were in themselves an evident precursor of that movement. Books of secrets provided the missing link between esoteric antiquity and empirical modernity.

[86] Henry, 3.

[87] Smith, 375.

The old bookends of Galileo (or perhaps Copernicus) and Newton, do not seem to fit our emerging perspective so neatly, nor does confining science and its import solely to the field of physics, but this is still where the action started and it was astronomy that guided the ships that connected the world. I suggest a view of the Scientific Revolution that recognizes the value of the ‘Great Tradition’ ***and*** the insights of the new broader based and inclusive scholarship. Modernity, heliocentric astronomy, and cross-oceanic navigation all witnessed their fitful births in this period. There is perhaps no determinative order to their emergence, and it is hard to argue that each or all could have existed in cultural isolation from other evolving trends, but their births were concomitant, intertwined, and related, as our examination of the actors involved illustrates. Science and modernity might have had many antecedents, but that does not argue for equality of impact. What is undeniable is that astronomical advances intertwined with the geographic discoveries of the early Age of Sail helped uproot the predominant medieval European epistemology and contributed to the emergence of dispassionate quantifiable scientific inquiry which we recognize today as one of the bedrock foundation stones of modernity.

CHAPTER 5.
The Rise and Apogee of Spanish Sea Power, Maritime Institutions, and State Secrecy; and Competition from the Protestant North

Spanish Rise to Overseas Dominance and Cosmographic Secrecy

Portugal and Castile clashed regularly throughout the *Reconquista*, both in Iberia and at sea. Despite the early Portuguese lead in Atlantic colonization, Fernández-Armesto states that Castilian ascendency in the Americas was almost inevitable, especially after they gained control of the strategically placed Canaries (critical in relation to the wind patterns for travelling west).[1] Like the Genoese before them and Elizabethan England following, the larger and more populous Castile started its naval ascendency through piracy and poaching upon the preserves of the established trading powers of its day. He goes further,

> "It is probably no exaggeration to say that, but for the accidents which made the Canaries Castilian, the New World could not have become predominately Spanish. Attempts to explore the Atlantic from the Portuguese islands of the Azores, like that of Ferdinand van Olmen in 1487, were doomed to be turned back by the prevailing winds."[2]

This embrace of geographic determinism ends with his dramatic conclusion that "Apart from Genoese surrogacy, it is the Canary Islands that are the key to everything that is most spectacular in the rise of Castile."[3] But Castile's rise in the Atlantic did not preclude Portugal's in the Indian Ocean and eastward. The rival powers signed several treaties in the late fifteenth century fixing spheres of influence seaward. The Treaty of Alcáçovas (1479-80) established a north-south division centered on the Canaries and also granted Castile sovereignty over the Canaries.[4] This

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[1] Fernández-Armesto, *Before Columbus,* 206, Castile's campaign to capture the Canaries was financially underwritten by the Genoese (as was the voyage of Columbus). He also notes (pgs. 155-157) that the initial Portuguese expeditions to the Canaries in the 1340s were underwritten by both Florentine and Genoese expertise, manned in part by Castilian mariners, and initiated an early role for Seville in navigational data collection.
[2] Ibid, 207.
[3] Ibid, 221. Similarly, the short-live French control of the Canaries was doomed for different geographic reasons: France held the Canaries but geographic proximity drove the Spanish project and doomed French one. (pg. 218)
[4] Gómez, 10 , "In a peace accord signed years before between Castile and Portugal, known as the Treaty of Alcáçovas (Toledo 1479-1480), Castile had recognized Portugal's sovereignty over that meridional expanse [a

treaty was replaced shortly after the Columbian landfall with the Treaty of Tordesillas in 1494 creating an east-west division that encompassed the globe.[5] This practice of dividing foreign or ancient ancestral lands up into spheres of influence had a long history in Iberia as illustrated in the Reconquista treaty signed by Jaime II of Aragon and Sancho IV of Castile in 1291where they divided old Visigoth-Romano Africa at the Moulouya River in modern Morocco.[6] The long-term efficacy of these treaties was of course debatable.

Treaties or not, Spain's dominance in Iberia and throughout Europe in the sixteenth century was assured by a confluence of dynastic politics and the new wealth provided by its American colonies. In 1516 the Duke of Burgundy ascended to the thrones of Castile and Aragon as Carlos I (Charles I). He was the first monarch to rule both major kingdoms of Spain in his own right. As the scion of three of the major dynastic families of Europe, he also added the Netherlands and the German and Austrian Hapsburg territories to his domain.[7] Elected Holy Roman Emperor in 1519, the newly crowned Charles V was involved in a series of dynastic and sectarian wars. He extended earlier Spanish gains in Italy and the Mediterranean, continually struggled with Valois France, and provided the main deterrence to Ottoman expansion in the Mediterranean and Eastern Europe. Under his early rule Hernán Cortés added the wealth and lands of the Aztec Empire (1519) to Charles' dominion with the establishment of New Spain in modern day Mexico and Central America. In 1533, Francisco Pizarro conquered the Inca

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latitudinal separation of spheres of influence to the south] in exchange for Portugal's recognition of Castilian sovereignty over the Canaries."

[5] Gómez, 19, Replacement of Treaty of Alcáçovas (north-south division at Canaries) with eventual Treaty of Tordesillas (1494) and accompanying papal bulls of Alexander VI creating a Castilian Portuguese divide of spheres of influence on an east-west line following the longitude 370 leagues west of the Cape Verdes Islands.

[6] Fernández-Armesto, *Before Columbus*, 127-128.

[7] Dynastic marriage alliances positioned the Hapsburg Charles to make the best claim for European 'universal monarchy' since Charlemagne. His legacy stemmed from three family lines:

(1) the Valois-Burgundy (Burgundian Netherlands and the Franche-Comté)
(2) the Habsburg (Austria and German principalities), and
(3) the Trastámara (Castile and Aragon).

The Hapsburg family had held the title of Holy Roman Emperor since 1440, a title which Charles was elected to after the death of his Habsburg grandfather, Maximilian I.

Empire and added Andean Peru to Charles' vast realm. This consolidation of power in one monarch would produce enmity in European rivals (especially in France, Germany, and Tudor England). It also inspired imitation, and due to the size of Charles' holdings, a diffusion of participation in the Castilian maritime project that would help undermine the Iberian overseas monopoly. Eventually we will examine this diffusion, and the role the Netherlands would play in recording and charting the Hapsburg discoveries, but first we will return to the Atlantic coast of Western Europe.

Although ratified by Pope Alexander VI (the Catalan Rodrigo Borgia), both the Protestant nations of northern Europe and the coastal Catholic monarchs refused to let their mercantile or colonial aspirations be bound by these Iberian treaties limiting their access to the eastern trade routes or the New World.[8] The European discovery of the Western Hemisphere and of the Indian Ocean sea route would inspire centuries of European competition for overseas domination. In this competition nautical information and cosmographical knowledge would become highly prized properties of the state. The knowledge accumulated by the returning Iberian pilots and catalogued by state sponsored cosmographers was heavily regulated and censored and became one of the primary targets of foreign intrigue.

Renaissance cosmography in Spain (a holistic blend of geography, cartography, ethnography, natural history, history, and astronomy) owed its paternity to the Portuguese Atlantic exploration project and as Maria Portuondo notes in her *Secret Science: Spanish Cosmography and the New World*, a humanist revival of "three classical intellectual traditions:

[8] Taylor, E.G.R., *A Regiment for the Sea and other Writings on Navigation*, 5, "The exclusive rights of possession and exploitation in newly discovered territories which in 1493 the Pope had granted to Portugal and Spain were, as might be expected, early challenged by other sea-board countries, and particularly by France. French pirates and French 'illegal' traders (usually Huguenots) were soon frequenting the shores of West Africa, Brazil and the West Indies."

Aristotelian natural philosophy … Euclidean geometry and Ptolemaic geography."[9] However, even within this tradition, there were divisions. Nicolás Wey Gómez has argued that "Columbus's project was forged between two diametrically opposed explanations about how earth and water had come to be lodged at the center of the cosmos and about how life had come to be allocated in the region of the four elements."[10] In essence this fifteenth century Western European cosmological debate had four main points of contention.

(1) Eurasian-African lone island versus a water globe with other land masses
(2) Northern-southern extremes of cold and fire; but world was larger to the north-south and to the east-west than allowed for in Ptolemaic cosmology
(3) Five zone theory of inhabitability (Ptolemy) vs. universal global fertility (Columbus and his camp)
(4) Temperate world with Mediterranean at its center versus a large multi-climatic world with the Mediterranean on its fringe

This debate would be resolved by discoveries that would not just clarify interpretations of the Aristotelian world view, but that would eventually lead to a rejection of the predominant epistemology of the West since antiquity.[11] However, these answers came slowly and better cosmographic information provided the rival European powers with distinct political and commercial advantages for crucial periods of time.

Alison Sandman has examined the issue of controlling geographic knowledge in the early modern period with reference to Atlantic cartography and navigational knowledge. Using Spain

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[9] Portuondo, Maria, *Secret Science: Spanish Cosmography and the New World*, 21, examines the humanist epistemological foundations of Renaissance in sixteenth-century Castile and its eventual mathematical empiricist offspring that emerged by the end of the Century of Discovery.

[10] Gómez, *The Tropics of Empire*, XIII.

[11] Gómez on major fifteenth century scholarly sources that formed Columbus's worldview – directly or through the views of contemporary scholars and navigators:

(1) Claudius Ptolemy's *Geography*, 2nd century AD – spirited out of a besieged Constantinople and translated into Latin at the turn of the fifteenth century (Pg. 61**,** "provided the technical knowledge that helped transform map making in the Age of Exploration."); and Pg. 67, "Jacopo d'Angelo's 1406 translation of Ptolemy's *Geography*, the work that established the methods and data of a field we now understand as 'cartography.'"
(2) Marco Polo's *Il milione*, 13th century
(3) Aristotelian corpus (open geography argument with short sea route from Pillars of Hercules to eastern tip of orient – *De caelo* – Pg. 232)
(4) Albertus Magnus's *De natura loci*, 1251-1254
(5) Pierre d'Ailly's *Ymago mundi* (Image of the World), 1410

as her case study, she illustrated the conflicting goals facing the royal government, specifically its need to both constrain and disseminate this knowledge. Political and diplomatic desires for staking claims conflicted directly with the crown's desire to protect its monopolies and shield its shipping from the state sponsored piracy of its competitors. The need to provide ship pilots with the most up to date information invariably created a large system prone to leaks and theft. She examined the contradictions that existed between metropolis regulations and actual practice at sea and concluded that this state of affairs reflected the uneasy balance reached between actors with conflicting state objectives. The Spanish state managed its conflicting objectives through two central state bureaucracies specifically involved in Spain's overseas project.

Portuondo also chronicles the concomitant role that secrecy played in state cosmography during the expansive reign of Philip II and the eclipse and reversal of secrecy policy through the ascension of Philip III and his reign of consolidation. She posits that the regal patronage undergirding Spanish cosmography led its adherents to develop a descriptive utilitarian science that catalogued and measured the natural world and the flood of information coming into Seville from the *carrera de Indias*. This project admirably supported long distance oceanic trade and empire, but never challenged the Aristotelian natural philosophy embraced by medieval scholastics. New cosmographical data that ran contrary to classical texts was accepted, but the undergirding epistemology that produced those errors was not jettisoned – it left unchallenged the "philosophical underpinnings of Aristotelianism."[12] This new Spanish science of cosmography, although sharing some empiricist, legalistic, and organizational characteristics with the Baconian method, did not seek causal reasons for the occurrence of natural phenomena. Spanish cosmography did not lead to modern science, even after it shed its cloak of secrecy, because it only sought to answer who, what, and where. It did not ask why.

[12] Portuondo, 302.

The Castilian crown created the *Casa de Contratación de Sevilla* in 1503 to oversee all commercial ventures in Spain's overseas territories, the *Indias Occidentales*.[13] This institution was also responsible for training and licensing pilots and directing the progress of navigation. Sandman notes "The laws governing pilots were equally clear. … Only native or naturalized Castilians were eligible to be licensed as pilots, and they had to provide information about their eligibility before they could even attend cosmography classes, let alone convene a tribunal for the mandatory licensing exams."[14] These pilots were not the only individuals that handled critical information. Sandman adds that "Instrument makers were also licensed by the *Casa* [*de la Contratación*], though these licenses were intended for quality control and to limit competition rather than to control information."[15] Seville became the largest and wealthiest city in Spain by the end of the sixteenth century and the crown reaped huge rewards from the royal trading restrictions, but the rest of Spain did not.[16] The Genoese colony in Seville provided the early financing for much of the trade and merchants from throughout Western Europe provided the capital and trade goods Spain was unable to produce herself.

Spain also established the Royal Council of Indies to govern its overseas possessions and regulate the production and dissemination of all cosmographical information coming out of the New World. Portuondo observes that,

[13] Gómez, 161, this included all territories "to the west and *south* of El Hierro island [Canaries]." This claim conformed to the Treaty of Alcáçovas and the Treaty of Tordesillas, as well as complying with the Alexandrian Bulls and recent northern European Labrador claims.

[14] Sandman, "Controlling Knowledge: Navigation, Cartography, and Secrecy in the Early Modern Spanish Atlantic," chapter 1 of Delbourgo and Dew (editors), *Science and Empire in the Atlantic World*, 35.

Cavendish, Richard. "The Casa de Contratación Established in Seville." History Today, 53:1 (January 2003), this prohibition did not extend to the position of Chief Pilot (Navigator) in the early days of the institution. The Florentine Amerigo Vespucci was appointed to this position in 1508. And as we will address below, the Venetian Sebastian Cabot would also hold this position.

[15] Sandman, 36.

[16] Cavendish, "the idea that such a web of human activity could be controlled by a bureaucracy proved hopelessly unrealistic and for all the cascade of silver, Spain remained a poor country."

> "By the midcentury, the threats posed by foreign and internal enemies moved the monarchy to consider cosmographical work the equivalent of today's state secret. … The Spanish monarchy took the defensive posture of censoring and prohibiting the circulation of maps, geographic descriptions, and historical account about the Indies for strategic military and political reasons.
> … For most of the sixteenth century the Council acted to safeguard this knowledge from eager and relentless enemies who challenged Spain's political and spiritual hegemony over these lands."[17]

Where the Portuguese tried to safeguard their monopoly position in the spice trade by nationalizing the trading enterprise, Spain decided to control all information deemed essential to its overseas enterprise by making cosmology itself a state monopoly. In examining both of these strategies it is hard not to see the emergence of modern mores in each approach. Jan Glete observes "the Portuguese ships and the guns were primarily owned by the state. This makes the Portuguese enterprise look strikingly modern, but little research has been given to the sixteenth century Portuguese navy as a coherent organization."[18] In lauding the truly enormous organizational effort required to operate the Portuguese *carreira das Índias,* Glete adds that the truly "innovative behavior" derived from two kings, Joao II and Manuel, acting more like merchants than feudal princes. Waters observes that

> "The Portuguese on the other hand ruthlessly kept secret all their discoveries along the route to the East Indies. Sufficient information was released for the maps of the world to be kept corrected, but the rutters and charts were rigorously protected by law from falling into foreign hands. Pilots experienced on the routes were closely watched."[19]

This defense of corporate secrets through a tightly held familial/national organization was however short-lived. The Spanish approach, also harkening the modern, was more durable. Establishing state bureaucracies tasked to accumulate and safeguard information was equally innovative and was generally successful for the better part of a century. However, very much

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[17] Portuondo, 6-7 and 103. Also pg. 104**,** the *Casa de la Contratación* was under a secrecy decree since 1510, the Royal Council since 1560, and pg. 123, "Just as the cosmographical description of the Indies was considered a state secret, so too was its history."
[18] Glete, 89.
[19] Waters, 82.

like their modern equivalents, over time these organizations would become susceptible to intrigue and internal betrayal.

The Spanish monarchs, like the Portuguese, had to train pilots, disseminate cartographic information essential to ship survivability, and at the same time keep its competitors from poaching upon its dispersed and lightly guarded colonial networks. According to Portuondo, Spain's "Cosmographers tackled these problems … and created a uniquely Spanish cosmographical genre – one with deep Portuguese roots: the navigation manual."[20] This synthesis of astronomical navigation (fixing position by latitude and distance travelled versus dead reckoning by compass bearing) and 'how to' manual was a codification of Spanish navigation practice. Even though the Council censored such publications, a number of these manuals reached northern Europe and were used by the budding privateer forces of Spain's enemies to prey on her shipping and colonies. When Admiral Sarmiento de Gamboa's received a copy of the limited publication of cosmographer-chronicler Juan López de Velasco's *Sumario,* he insisted that the Council "add the following notice to the cover: 'It is in His Majesty's service that this not be copied or moved without authorization from the Royal Council of Indies,' the early modern version of a red 'top secret' label."[21]

However, the Spanish censorship was not airtight. In 1551, Martín Cortés de Albacar, a pilot instructor and lecturer on cosmography and navigation, published the standard navigational reference for Spain, the *Breve compendio de la sphera y de la arte de navegar, con nuevos instrumentos y reglas, ejemplificado con muy subtiles demostraciones* or more simply, *Arte de navigar*. This doctrinal classic, brought back to England by Stephen Borough would be

[20] Portuondo, 56.
[21] Ibid, 196.

translated into English by Richard Eden as early as 1561 as *The Art of Navigation.*[22] Obtained by England during the mid-century warming of Anglo-Spanish relations during the reigns of Edward VI and Mary, and the period of Sebastian Cabot's Muscovy Company ventures, the widespread dissemination of this manual among the more learned captains would be essential in the development of English maritime capabilities.[23] First in its translated form, it became the standard manual of explorers, pirates, and instrument makers alike.[24] Later, as we shall address, it became the basis for William Bourne's far more practical *Regiment for the Sea*, which was aimed at a much wider maritime audience. As we experience today, national or trade secrets shared with allies, often become competitive liabilities as allegiances change. Spain generally attempted to prevent the flow of instructional and computational manuals like the *Arte de navigar,* and it guarded hydrological and meteorological information as well.

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[22] Taylor, E.G.R., 7, in the editorial remarks preceding William Bourne's *An Almanacke and Prognostication for three years (1571-1573)*, which work preceded his *A Regiment for the Sea*.

[23] Taylor, *A Regiment for the Sea*, 6-7, Cabot was asked to join the Muscovy Company at the beginning of the short reign of Edward VI. Stephen Borough was invited to Spain to witness pilot training at the end of Mary's reign. Mary, as the wife of Philip II and champion of the brief reintroduction of Catholicism to England, did a great deal to further the development, with Spain's guidance, of England's navigational skill and ship building prowess. That this tutelage would be most beneficial to Elizabeth's Sea Dogs, and equally as injurious to his Most Catholic Majesty, is one of history's great ironies.

[24] Ash, Eric, *Power, Knowledge, and Expertise in Elizabethan England,* 142, notes that Eden's translation "was the first navigation manual printed in England."

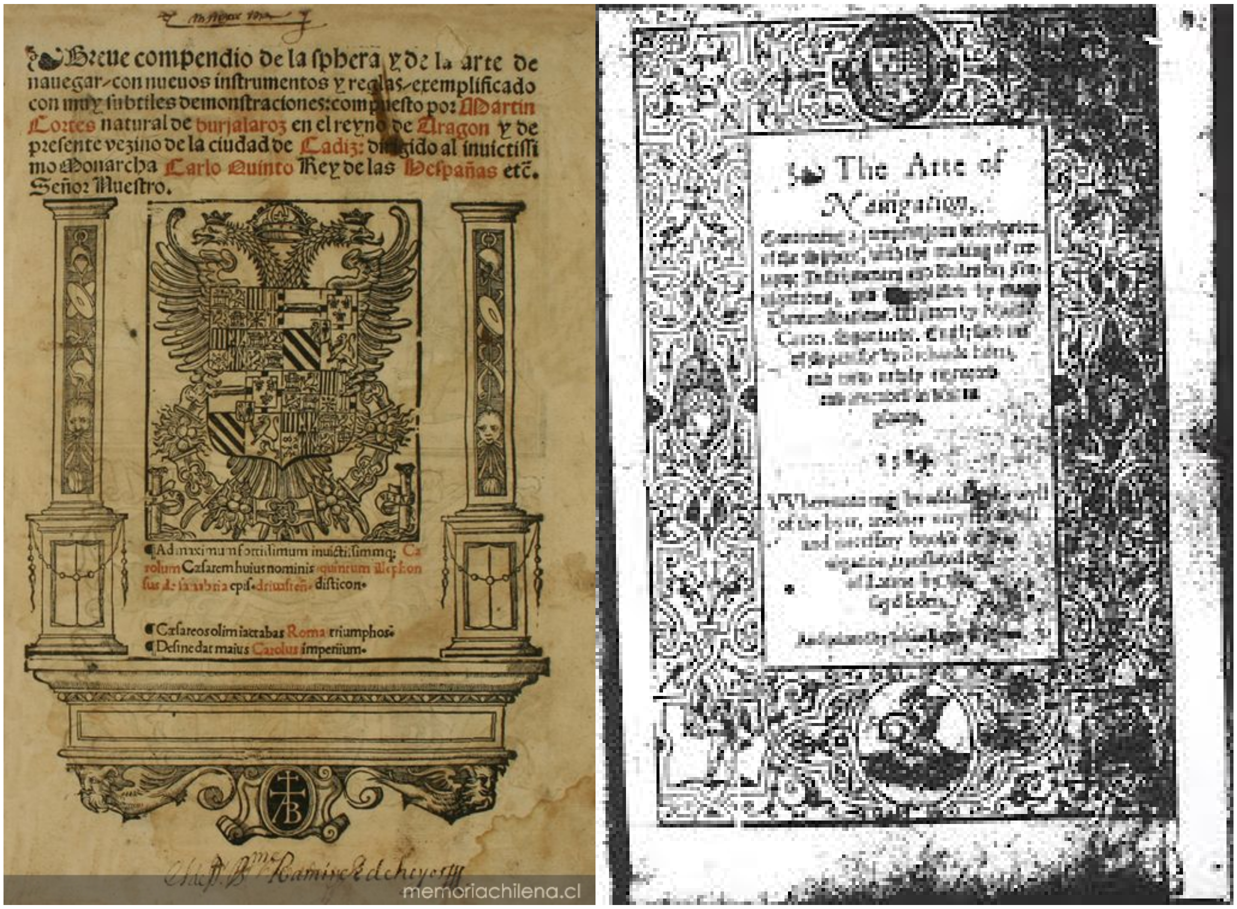

Figure 5.1. State Secrets and Ambitious Allies. *Arte de navigar* of Martín Cortés from 1551, the navigation textbook of Hapsburg Spain, and its 1561 English translation by Richard Eden (cover page from the 1584 edition), which became the training manual of this erstwhile ally first for its Muscovy Company expeditions, but rapidly for imperial predators like Francis Drake or Martin Frobisher.[25] David Waters contends that it "was one of the most decisive books ever printed in the English language. It held the key to mastery of the sea."[26]

When Spain founded Manila in 1571 in the Philippines to establish a China trading post, it closely controlled the information it had discovered about the Pacific and its wind patterns. Samuel Bawlf, in his *The Secret Voyages of Sir Francis Drake, 1577-1580*, notes that

> "To protect their foothold in the Orient, the charts and sailing directions for the voyage were closely guarded. They were issued to the pilots only upon their departure and had to be given back to the authorities, along with the log of their just completed voyage, immediately upon their return."[27]

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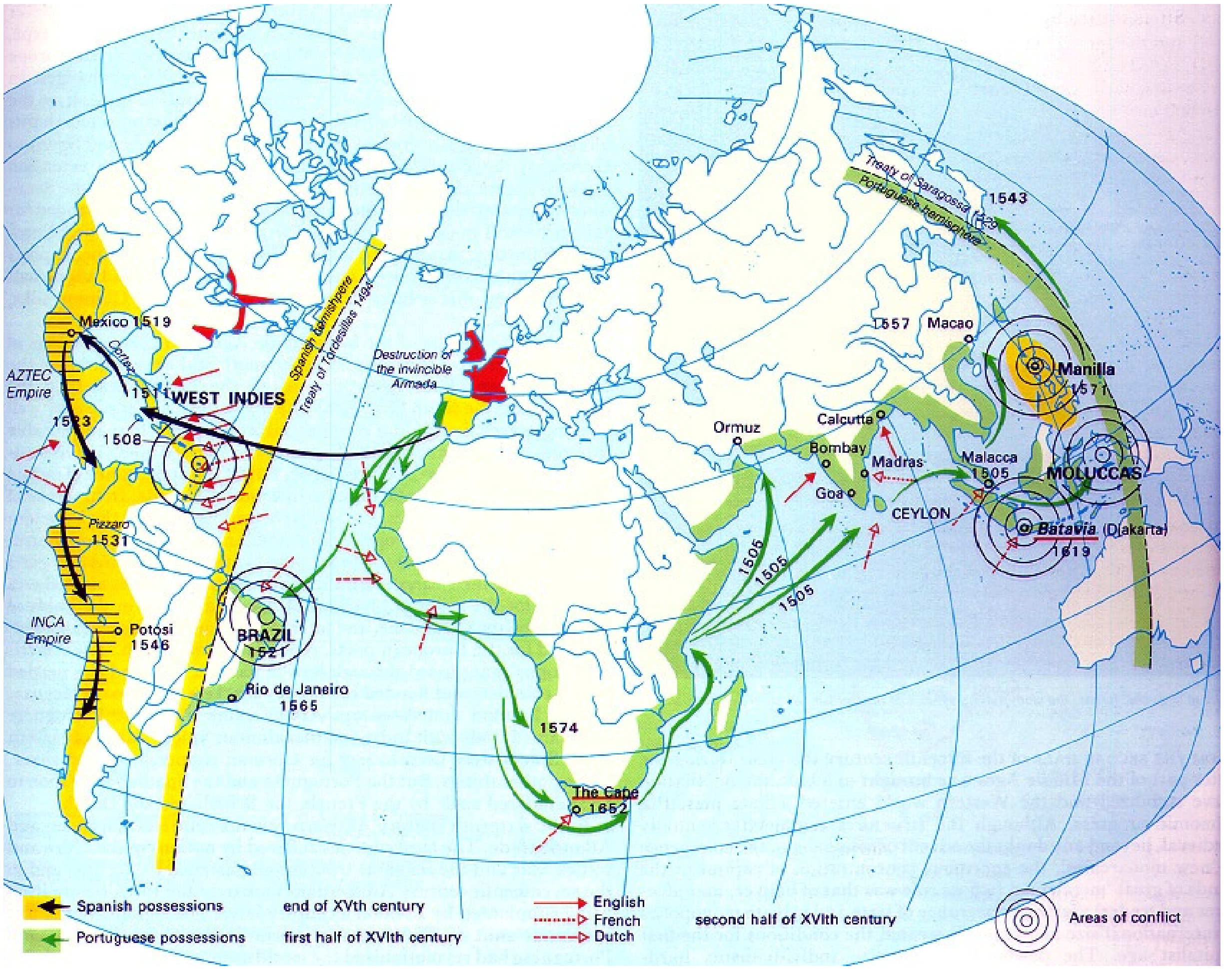
[25] National Library of Chile, Memoriachilena.cl, http://www.memoriachilena.cl/602/w3-article-10038.html and Cunningham, Richard, Acadia University, "Coincidental Technologies: Moving Parts in Early Books and in Early Hypertext," Plato.acadiau.ca, http://plato.acadiau.ca/courses/engl/rcunningham/CC/CoTech.htm.
[26] Waters, 104.
[27] Bawlf, Samuel, *The Secret Voyages of Sir Francis Drake, 1577-1580,* 46.

The Manila Galleon returning to Spain's New Mexico once a year laden with the porcelain, jade, and silk, exchanged for New World silver, was often a target of privateers.

However, the Spanish state did not limit its manipulation of cosmographic data to prohibitive actions, such as censoring information about sailing directions or ensuring pilots were loyal nationals. It also applied a very modern method of compartmentalizing cosmographic knowledge regionally to prevent leaks, with the Council being the only repository of all the Empire's knowledge. Portuondo states that "Each administrative unit was encouraged to 'know' its own affairs and territory but prohibited from learning the whole."[28] Spain also actively distorted cosmographic information for political purposes. For example, in order to justify the claim to the Philippines and comply with the Treaty of Tordesillas, Spanish cosmographers reduced the distance across the Pacific Ocean between North America and China on its published maps in effect pulling their archipelago across the Spanish side of the 180 degree far side demarcation line. As Bawlf describes, "To support his claim to the [Philippine] Islands, Philip [II] had his cartographers produce maps that understated the sailing distance across the Pacific, and argued that the line of demarcation actually cut through the Strait of Malacca, 1,000 miles further west."[29]

[28] Portuondo, 126.
[29] Bawlf, 45, political cartography in action – a deliberate distortion of science to push the 180 degree dividing line west of the Philippines.



Map 5.1. Empire and Deceptive Cartography: The line of demarcation first established by the Papal Bull of Alexander VI at about 37°W and moved westward about seven degrees in 1494 by the Treaty of Tordesillas to about 45°W (370 leagues west of the Cape Verde Islands – neither longitudes, the length of a league, nor a precise point of departure were delineated in the treaty); it established the Iberian hemispheric zones of control of the non-Christian world.[30] In order to legally secure their Philippine possession and maintain their highly lucrative Manila Galleon, Spanish cosmographers had to shorten their reported distance across the Pacific from New Spain (Mexico) to 'pull' the Philippines eastward across the Pacific dividing line or antemeridian established by the Treaty of Zaragoza in 1529.

However, most technological secrets are temporal and even nations adjust their policies when confronted with the futility of attempting to preserve a restriction of knowledge in the face of tacit dispersion or when they have more to gain by public declaration and claims to authorship. Sandman observes "that by 1562, the outlines of the [Atlantic Indies] route were assumed as common knowledge among seafarers. The Spanish were reduced to defending their

[30] Curry, S.D.L., "Treaty of Tordesillas," Sdlcurry.com, http://sdlcurry.com/treaty-of-tordesillas/.

territorial claims by force of arms rather than by geographical secrecy."[31] Ironically, Spain started to relax its secrecy requirements towards the end of the sixteenth century, even before the death of Philip II, just as one of its principle adversaries was both ramping up its piratical war of attrition against Spain and as it was simultaneously starting to assemble and protect its own nautical canon. However, Spain only formally shifted its stance on cosmographical secrecy with the ascension of Philip III in 1598. Portuondo contends,

> "The shift in secrecy policy signaled a radical re-conceptualization of the strategic value of geographic knowledge. Under Philip II, the value of geographic knowledge lay in how it could provide an intelligence advantage in the case of war or defense, or a way of protecting economic assets by keeping them 'hidden' from covetous enemies. For Philip III, geographic knowledge was most valuable if it could be deployed, albeit properly contextualized, to create a public image of Spanish domination and prestige. Demonstrating this knowledge to the public worked to create the perception that Spain, because it knew its territories so well, controlled them effectively."[32]

Henceforth Spain would use cosmography to assert its political claims and demonstrate its authority by publishing a good deal of its (tailored) information about its colonial possessions. However, England, having been a nautical laggard vis-à-vis Iberia for most of the sixteenth century, would not be so willing to share the oceanic knowledge it was steadily accumulating. Before we follow this though however, we will need to travel to the North Atlantic and the continental shore of the North Sea.

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[31] Sandman, 38.
[32] Portuondo, 260.

Dutch Capital, Cartography, and Printing Presses

> "The Spaniards though possessed of all the gold in the world remained or became poor; the Dutch presently acquired riches, without either lands or mines. Holland is a nation at the service of all the rest, but who sells her services at a high price. As soon as she had taken refuge in the midst of the sea, with industry and freedom, which are her tutelary gods, she perceived that she had not sufficient quantity of land to support the sixth part of her inhabitants. She then chose the whole world for her domain, and resolved to enjoy it by her navigation and commerce. She made all lands contribute to her subsistence, and all nations supply her with the conveniences of life."[33]
>
> Abbé Raynal, *A Philosophical and Political History of the Settlements and Trade of the Europeans in the East and West Indies* (Amsterdam, 1770)

The medieval Netherlands, the low lying coastal area and riverine delta region opening onto the North Sea had been a contentious border zone between Roman Gaul and the neighboring Germanic tribes for centuries. The destruction of the western empire and the ascendancy of the Germanic feudal kingdoms provided little relief to this region. Its easy access to North Sea coastal incursion brought the region little security under the Holy Roman Empire. Its history in the early modern period was equally tumultuous. The Burgundian ducal ancestors of Charles V had added a large portion of this area to their domain by 1433, renaming this area the Burgundian Netherlands and bringing it under the nominal suzerainty of France. Charles brought this complicated paternity to his new Spanish kingdom. Direct Spanish rule under Charles and his heirs, and the upsetting of long standing local privileges enjoyed by the all but autonomous counties and cities promulgated enmity toward Spain. However, this rule did provide some organizational unity in the northern portion of the country imposed by Spain in the form of the Estates General. The Lutheran sectarian rift with Rome and the widespread acceptance of Lutheranism and Calvinism in the north (approximating modern day Holland) increased anti-Spanish sentiment. Ensuing rebellion engendered Spanish reprisals and after a

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[33] Raynal, Abbé, *A Philosophical and Political History of the Settlements and Trade of the Europeans in the East and West Indies* (Amsterdam, 1770), Book XIX, 495-496, Volume V of X, Translated by J. Justomond, 3rd ed. 1777.

long series of wars, a sectarian separation within the Low Countries. The long Dutch Revolt (1568–1648), also referred to as the Eighty Years War, resulted in a severed Burgundian Netherlands into a Catholic French and Dutch-speaking Spanish Netherlands in what is today Belgium and Luxembourg, and a northern Protestant Dutch speaking United Provinces, the modern Netherlands.[34]

It is this period of direct Spanish control that concerns us presently. Situated in an exposed and changing landscape, under constant reshaping and threat from the North Sea, the various peoples of the Low Countries over the centuries had a long acquaintance with this sea and the neighboring Baltic and North Atlantic. Like the Venetians to the south, this fortuitous central placement along seaborne trade routes would prove very advantageous as trade rebounded in Europe in the High Middle Ages. David Onnekink, in his review for the English State Papers Online entitled, "The Dutch Republic," has noted

> "The backbone of the Dutch *entrepôt* was its role in connecting two important trade routes, that of the traditional Baltic trade (grain, timber) and of the newly-gained Levant trade (luxuries), complemented by the East India spice trade that took off in the last decade of the sixteenth century."[35]

Felipe Fernández-Armesto has also observed a similarity between the early Dutch and the previous century's rising naval power. He notes that the rise of both the Portuguese and Dutch maritime empires was preceded by years of piracy and fishing in neighboring waters. Echoing Braudel's focus on fish, Atlantic tuna drove the early Portuguese maritime initiatives as we have

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[34] Schmidt, Benjamin, "The Dutch Atlantic: from Provincialism to Globalism" in Greene, Jack P., and Morgan, Philip D., *Atlantic History, a Critical Appraisal,* 167, "the Dutch did not, strictly speaking, become Dutch until they revolted against Hapsburg Spain in the late 1560s. Until then traders, sailors, soldiers, missionaries, and other[s] …[were] taking part in the evolving [Hapsburg] 'enterprise of the Indies.'" Early period of Dutch involvement in maritime project; Phase I (1492-1560), support, trade, and publishing.

[35] Onnekink, David, "The Dutch Republic", State Papers Online, 1509-1714. "Moreover it was mainly on Dutch ships that this trade was carried …For the larger part of the seventeenth century, Amsterdam was the leading trading metropolis and staple market in northern Europe. Successes in trade created a solid economic foundation on which the Dutch Golden Age could be built."

discussed, while pursuit of North Sea herring drove the early Dutch.[36] In addition, both nascent maritime powers had early financial backing from technically adept and financially flush neighbors; the Italian Republics and Flemings respectively.[37]

However, equally important in the rise of the Dutch was its status as the cartographic center for Charles V's and Philip II's far flung Hapsburg Empire. As such, the great cosmographers, publishers, and map makers of Amsterdam and Antwerp became privy to the torrent of new world data flowing into the *Casa de Contratación de Sevilla*. As Benjamin Schmidt notes in his essay "The Dutch Atlantic: from Provincialism to Globalism" in Jack P. Greene's and Philip D. Morgan's, *Atlantic History, a Critical Appraisal*,

> "Spanish news and, more important, publications swiftly became available in the north. Original histories of the *Conquista* were promptly translated into Dutch, French, and Latin; and some Spanish-language texts had their debut in Antwerp editions, a reflection of the superior printing facilities of the Netherlands as well as the restrictive rules of Spanish censorship."[38]

The Dutch at first were active participants in the Iberian Atlantic enterprise. Schmidt goes on,

> "The Low Countries by this time also occupied the center of the cartographic trade, and this meant that maps, and (by 1570) atlases conveyed still further images of the Atlantic. As with literary sources, however, Dutch geographic texts tended to abet, rather than defy, Spain's imperial ambitions."[39]

He presents the great Flemish cartographer Abraham Ortelius' effusive dedication of his *Theatrum orbis terrarium* to Philip II as illustrative (presented in Chapter 6).

The nascent Dutch would not remain content junior participants in the Hapsburg Atlantic enterprise. As the sixteenth century wound down, the rebellious seven Northern provinces that

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[36] In a similar vein, Newfoundland Banks cod would be largely responsible for early English and Breton offshore Atlantic exploration.

[37] Fernández-Armesto, *Before Columbus,* 217.

[38] Schmidt, 167. Endnote #6, pg. 183, lists several examples including the near simultaneous printing of Hernán Cortés's letters to Charles V in the Low Countries and in Spain.

[39] Ibid, and Glete, 170, notes that "unlike the English and the French, the Dutch had up to then showed little interest in plunder and interloping trade against Spanish and Portuguese interests overseas." The Spanish embargo would alter this calculus much to the regret of Imperial Spain.

would comprise the tiny Dutch Republic declared independence from the world's first global superpower. The Hapsburg reaction was both violent and broad and included placing the region under economic embargo. Glete has noted the proto-capitalist Dutch's novel response;

> "the Spanish embargo policy was confronted with a totally different Dutch policy, where 'trading with the enemy' (*handel op den vijand*) was officially approved. … The Dutch state, and particularly its navy, [sold] licenses (*licenten*) for trade with the enemy. … It was a policy based on the belief that economic activity which gave Dutch capital opportunity to gain profits also gave the Dutch state financial muscle to wage war."[40]

Blocked from trade with Europe, the Dutch traded directly with America, Asia, and Africa. The 'territorial states' of Europe were in the end defeated as Glete notes, by a state

> "created by an elite of capitalist entrepreneurs. … The combined effect of Dutch efficiency in trade, shipping, and warfare at sea, the Spanish embargoes and Spain's inability to protect her own European shipping was that Holland and Zealand became the first central entrepôt for world trade."[41]

Whereas Spain viewed the sea as a venue for spoils for aristocrats, the Dutch saw an opportunity for capital formation. Spain taxed trade for the benefit of the crown and landed elite.[42] The Dutch taxed trade for the benefit of traders. This unfettered and aggressive use of private capital for national aggrandizement was not the only novelty the Dutch introduced into their struggle for independence.

Another modern weapon the Dutch would use to liberate themselves from Spain and begin their ascent to assembling a global trading empire and a navy rivaling any in Europe, would begin with the printing press. In the early stages of the Hapsburg Atlantic enterprise the Dutch were great propagandists for the opening the Atlantic. Schmidt notes that the Dutch

> "… produced some of the most enduring images of the Atlantic in the form of geographies, natural histories, atlases, maps, prints, paintings, and other sources that revealed the Americas and Africa to a growing market of European consumers. … The

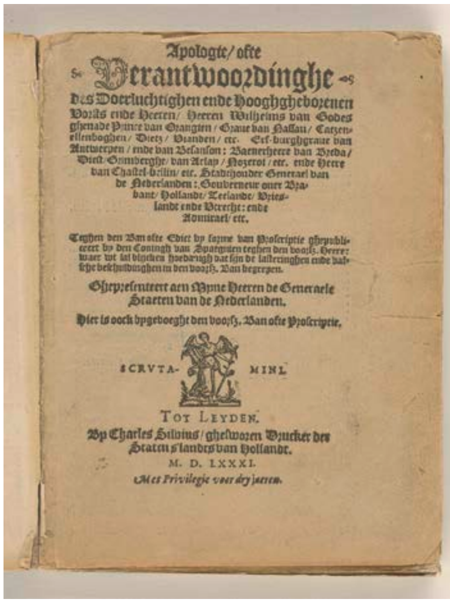
[40] Glete, 166.
[41] Ibid, 167.
[42] Cavendish, "The American colonies were treated as the crown's private property and the Casa was meant to steer the maximum amount of money into the royal treasury."

> Dutch wrote about and debated the meaning of America in scores of texts and prints – famously, those illustrating editions of Las Casas, which poured off Dutch presses."[43]

They would turn these presses against the Hapsburgs with vehemence and in the process lay the foundation for the Spanish 'Black Legends' and the new polemic warfare enabled by the printing press. The 'prince of pamphleteers,' William of Orange "In his widely circulated *Apologie* of 1581, the leading grandee of the land painted the blackest of portraits of Spanish 'barbarities,'"[44] Seaborne entrepreneurs, propaganda, and printing presses, when combined with the religious fervor propelling the dissolution of a Universalist Christendom, enabled this new nation of less than 2 million people to successfully confront the Hapsburg hegemon and nations nearly ten times its size like France.[45] However, jealousy of Spanish colonial wealth coupled with religious affinity also prompted Tudor England and parts of Huguenot France to align themselves, even if tentatively, with the upstart Republic.[46] These alliances, especially the dispatching in 1585 of the English expeditionary force under the Earl of Leicester, following the chaos that ensued from the Prince of Orange's murder in 1584, to actively confront Spain in the Low Countries would be one of the major factors which ended the long 'cold war' between Elizabeth's England and Philip II and in turn motivated the launching of the Spanish Armada in 1588. Moreover, the English would learn quite a deal from the ensuing maritime confrontation and from Dutch

[43] Schmidt, 165. Dutch writing and speculation about "cultural geography of the 1570s and 1580s preceded significant activity in the Atlantic by several decades."
[44] Ibid, 168. "The transition of the Dutch Atlantic from source of pride to invective can be dated fairly precisely to the year 1568, when a group of Dutch nobles contested the king's policies in the Netherlands, protesting that 'the Spanish seek nothing but to abuse our fatherland as they have done the New Indies.' This marked the commencement of the Dutch Revolt."
[45] Beloch, Julius, "Die Bevölkerung Europas zur Zeit der Renaissance" in *Zeitschrift für Socialwissenschaft*, 1900, pp. 765 to 786. Estimates of population in 1600: Italy, 13M; Spain and Portugal, 10M; France, 16M; England and Wales, 4.5M; Scotland and Ireland, 2M; Netherlands, 3M, including the Spanish Netherlands; Denmark, Sweden, Norway, and Finland: 2M; Poland with Prussia: 3M; Germany: 20M.
[46] Storrs, Christopher, "The 'Decline' of Spain in the Seventeenth Century", State Papers Online, 1509-1714, notes that the eventual decline of Spanish dominance could have been itself a result of the preceding lack of able competitors caused by the rampant internecine warfare throughout the states of possible early Atlantic contenders. As these states stabilized and asserted their influence, in particular the French under the reign of Louis XIV, Spanish European hegemony naturally receded before the weight of balance of power politics.

financial innovations. As we will address in Chapter 8, Dutch printing, modern financial arrangements, and the skillful propaganda of a future William of Orange would have a marked impact on England's state institutions in the seventeenth century. But first we will return to the twilight of England's Spanish apprenticeship and her first battle for control of the Atlantic.



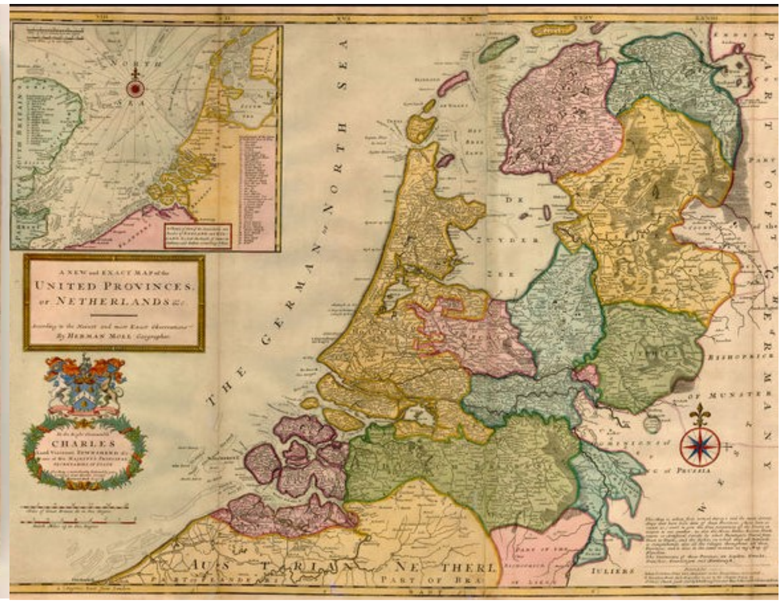


Figure 5.2. The 'Apology' or Defense of William of Orange against The ban or edict of the King of Spain, 1581.[47] William's pamphlet was emblematic of the new Dutch weapon of war – the printing press. The presses of the Low Countries for decades had been used by the Hapsburg's to promote the Atlantic adventure and create a European market for the fruits of oceanic trade. The Dutch rebellion initiated not just Dutch overseas plunder of Iberian colonies and the inception of the Dutch maritime empire, but the birth of mass-produced printed propaganda as a weapon of war. The product of this propaganda and the subsequent 'Black Legends' of Spanish Imperial conquest have left their biased mark on this history for centuries.

Map 5.2. The Seven United Provinces of the Netherlands; produced by the Eighty Years War.[48] The seven provinces of the seventeenth century Dutch federation were semi-independent and not all wed to the sea. Seats in the States-General were allocated proportional to provincial tax contributions, of which Holland paid 60%. Despite internal rivalries between Amsterdam and Rotterdam, Holland generally favored policies aiding the Baltic and Mediterranean carrying trade, and the trade to the East Indies (*Vereenigde Oost-Indische Compagnie* or VOC). The other maritime province, Zealand, favored the interests of fishing, privateering, slaving, and West Indies (*Westindische Compagnie* or WIC) trade. Both favored republican politics. The other five provinces were generally land oriented and agricultural. They looked to the army and the House of Orange-Nassau for the protection of their interests.[49]

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[47] Duke, Alastair. "William of Orange's Apology: A New Annotated English Translation." *Dutch Crossing: Journal of Low Countries Studies*, **22:1** (1998). Dutchcrossing.org, http://www.dutchcrossing.org/ojs/index.php?journal=dutch-crossing&page=article&op=view&path%5B%5D=70, "In 1580 the Spanish … issued the Edict of Proscription, which accused William of Orange of being … the sole head, author and abettor' of the Revolt of the Netherlands, and placed a price on his head." William's '*Apology*' was "written in French and translated into several languages for international distribution. … [The] document marked an important new stage in rebel propaganda," directly blaming King Philip and prompted the 1581 Act of Dismissal.

[48] "United Provinces," Mulierchile.com, http://www.mulierchile.com/united-provinces/united-provinces-006.jpg.

[49] Rodger, N.A.M., *The Command of the Ocean: A Naval History of Britain, Vol. 2, 1649-1815*, 8-9.

Early Tudor Research Programs and Institution Building

Even though the English had a long seafaring tradition and were fishing the shallow Newfoundland banks in the fifteenth century, the English involvement in the early chapters of Atlantic exploration was both brief and interrupted. Henry VII (r. 1485-1509) entertained and rejected a proposal presented by Columbus's brother for his Indies expedition before Columbus could secure Castilian sponsorship. After the latter's shattering success, Henry Tudor did sponsor the Venetian mariner Giovanni Caboto (John Cabot) in 1497, directing him to find a passage to Cathay (China) for England north of the Spanish discoveries. Cabot found Newfoundland and hopes of a Northwest Passage to the Orient, but weather, ice, and the fragility of fifteenth century shipping halted the effort. His son, Sebastian, pushed this exploration further northward in 1508, but lost continued English support, and ended up working for Spain (eventually as Pilot Major of the *Casa de Contratación*).[50] England would not seriously re-enter the exploration business until Henry VII's grandson sat on the throne, when members of Edward VI's Privy Council rehired an aging Cabot almost a half century later to run its new Muscovy Company.[51] In his definitive *The Art of Navigation in England in Elizabethan and Early Stuart Times*, David Waters asserts that,

> "At the time of Henry VIII's death [January 1547] few Englishmen could navigate a merchant or royal ship across the great ocean to a known landfall. None could navigate to the East – to India, the Moluccas, [and] Cathay. Nor had any Englishman penetrated the vast spaces of the Pacific Ocean – of the Great South Sea."[52]

Sandman and Ash echo this assessment and contend that "Exploration had all but ceased under Henry VIII (1491-1547), and though English trade generally flourished, it also became

[50] Bawlf, 41.
[51] Sandman, Alison and Eric Ash, "Trading Expertise: Sebastian Cabot between Spain and England," *Renaissance Quarterly*, **57** (2004), 829.
[52] Waters, 79.

ever more concentrated on a small number of exports [wool] and nearby markets."[53] They highlight the fact that the English seafaring tradition had decayed as opposed to having been nonexistent. "While English ships had once been regular visitors to Iceland, the Mediterranean, the Levant, and the Hanse ports, by the middle of the sixteenth century they peddled their woolen wares almost entirely in a few key ports in Spain, France, and the Low Countries, particularly Antwerp." They also note that English fishing on the Newfoundland Banks, or off the "codfish island", was a distinct exception to this maritime decay, and in fact, Sebastian Cabot's knowledge of this fishery made his services attractive to the Spanish court.[54] However, Waters points out that this annual fishing trek was not oceanic navigating as practiced by the Iberians.[55] Upon returning to England, Cabot wanted to continue his search for the Northwest Passage, but the London merchants wanted him to find a Northeast Passage instead, and installed him as head of what became the Muscovy Company.

However, even though Henry VIII (r. 1509-1547) did not contribute to the story of early European exploration, he did bequeath his heirs two important legacies: a blossoming ordnance industry and an institutionalized navy.[56] The fusion of these two legacies, Henry's Navy Royal,

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[53] Sandman and Ash, 829.
[54] Ibid, 817.
[55] Waters, 78, asserts that "In company with the more numerous Bretons and Normans, a few hardy [English] fishermen made the annual trip to the cod-banks and to the inhospitable shores of Newfoundland, there to cure their catch for return. But they were not navigators."
[56] Rodger, *Safeguard*, 169, notes that Henry VIII's navy building program was neither inspired by an overarching sea-borne strategy for increasing the power and prestige of England, or out of competition with the Iberian empire builders, but rather because of a more mundane, tri-partite threat from secondary powers – Scotts, Danes, and Bretons – menacing his waters or threatening invasion. He notes, 204, that "it was almost certainly the threat of the Scottish navy which inspired Henry to build his new big ships the *Mary Rose*, *Peter Pomegranate* and *Henry Grace à Dieu* (… the *Great Harry*)."

Konstam, *Sovereigns of the Sea*, 96, notes that James IV's "the [*Great*] *Michael*, produced by one of Europe's secondary powers, was truly a groundbreaking ship – one of the first gun-armed warships, and certainly the largest custom-built gun-armed warships when she entered service in 1512. … She represented the first step on that long road toward the floating gun battery that was the ship of the line, the ultimate sailing ship of war." He adds, 107-111, that Henry VIII responded with the larger and better gunned *Henri Grace à Dieu*, built in two years rather than five and more cheaply. He was also building naval institutions like Trinity House (1514), "a body dedicated to the safety of English mariners and the collection of navigational information."

was transformational in that it was purpose built around shipboard cannon and gunpowder. However, Henry VIII faced a serious obstacle in building a navy centered on modern gun platforms.[57] England lagged behind the rest of Europe in foundry technology, especially with regard to the most sophisticated and effective guns of the day, bronze cannon. Carlo Cipolla has speculated that the prevalence of iron ore in England led to a dismissal of an indigenous alloy craft (bronze is a mixture of copper and tin), but this ironically put England ahead in the new technological advance of cast iron cannon during the reign of Henry VIII.[58] Regardless, the relatively free flow of raw materials and experts in Early Modern Western Europe aided technological transfer and development. Henry VIII was able to both purchase the bronze naval guns he needed for his fledging navy from the Low Countries and import technological expertise in the guise of Italian gunsmiths.[59] Competent national secrecy apparatuses did not yet exist in

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However, these extraordinarily expensive ships were both ahead of the tactical developments in naval warfare at the time and beyond the limited financial capacity of these small northern kingdoms. He observes, 118-119, that the *Great Michael* was sold to France for a third of its value and the *Great Harry (Henri Grace à Dieu)* was mothballed for a tenth of her operational costs at least six months each year. Konstam concludes, 121, that with hindsight, the *Great Michael* and the *Great Harry* were failures.

[57] Konstam, Angus, *Sovereigns of the Sea: The Quest to Build the Perfect Renaissance Battleship*, 16, proposes that Henry VII (1485) was the actual founder of the Navy Royal because he was the godfather of English purpose-built warships. "The *Regent* and the *Sovereign* both carried a mixture of heavy and light pieces of ordnance, making them the first purpose-built gun-armed warships in northern Europe." The author caveats this assertion, 43, that Henry VIII, upon his ascension (1509), refitted the *Regent* and the *Sovereign*, which started the transition of sailing warships from infantry platforms to gun platforms carrying "true ship-smashing guns [with a] range of about 400 yards." Henry's refit included adoption of carvel-built hulls, reinforced to carry heavy ordnance and cut with gun-ports, with a "trend toward using fewer guns, but larger ones." Regardless, early Tudor naval tactics still centered on gunnery used to sweep decks as prelude to an infantry clash upon boarding.

Rodger, *Safeguard*, 221, no fan of Henry VIII, allows that it was "at the end of his reign that the crown first established a standing fleet of ships intended, and increasingly designed, for war. From this point the modern Royal Navy of Britain can trace a continuous history." He emphasizes that it was not size or number of ships, but a permanent support administration that made this new navy permanent.

[58] Cipolla, 39.

[59] Konstam, *Tudor Warships (1): Henry VIII's Navy,* 35, notes that "Although ordnance had been cast from bronze since the mid-fourteenth century, it was not until the first decade of the sixteenth century that the English truly embraced this new technology. Henry VIII imported skilled gun founders from Italy – Arcani (Arcanus) of Cesena and Jeronimo (Jeronimus) of Milan were both taken into royal employ, and produced bronze guns for the Navy Royal. … However, the majority of the bronze guns used on board Henry VIII's warships were imported, most being supplied by the gun founder Hans Poppenruyter of Malines, in Flanders.

Waters, 82, "In building up his royal navy Henry [VIII] gave it of the best – Italian shipwrights, French pilots, and German gunfounders."

Europe to effectively prevent the transfer of expertise and advanced technologies with military or commercial use across porous national borders. But this state of unfettered intellectual exchange was in its twilight.

Cast iron foundry practice in sixteenth century England also experienced a big technological leap. Various speculations have been suggested to explain this development including those centered on crediting the excellent grade of local iron, new molding techniques, expansion of iron working heuristics, and new caliber to length ratios. But as Cipolla notes, "Whatever the reasons for the technological success, we know that it turned into an economic one. As has been pointed out [Schubert], 'the manufacture of guns was the most profitable proposition in the sixteenth century iron trade.'"[60] His survey of the early history of the embryonic European cast iron cannon armament industry reads like today's headlines with regards to its cutting edge technology and political economy and in this history we can glimpse the emergence of some of the national secrecy apparatuses that would come to define future interstate relations regarding 'dual use technologies.'[61] This industry also serves as an early example of practical, cost effective manufacture featuring function over ornament and quantity over quality that later characterized other English industries like linen. These cheaper guns (a

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Rodger, *Safeguard*, 213, "Henry of course was not the wealthiest prince, and all the copper for bronze guns had to be imported. So, initially, were the guns themselves, and the French and Italian experts to teach the English gun founding."

[60] Cipolla, 40.

Rodger, Safeguard, 214, notes that iron was plentiful in England were copper was not. The English could make cast iron guns at 10 to 20% of the price of bronze. The Tudor Ordnance Board nursed the industry for 30 years, so that by the Elizabethan Age, England had gone "from importing almost all their heavy guns … to regulating the export of a weapon of which they were virtually the only manufacturers."

[61] Reading through Cipolla provides a number of examples:

Pg. 43: "national champions" – Queen Elizabeth grants national export monopoly 1567

Pg. 44: "export restrictions" – Elizabeth bans sale of cost effective guns to Catholics

Pg. 49: "substandard clones" – Spanish failures to mimic and establish an indigenous industry

Pg. 54: "foreign competition" – Sweden's quick mastery of techniques and market capture propelled by concerted study of existing knowledge base and exploitation of trade

Pg. 66: "protectionism and critical industries" – France's Colbert mandates local purchase even if inferior, to protect and grow fledgling industry critical to French national defense/pride third of the cost of bronze)[62] would eventually be produced in mass for England's growing maritime establishment, even though Henry VIII's principle naval guns would remain bronze.

Henry VIII did more for the Navy Royal than just quadruple its size and introduce modern gunnery as its core armament. He also established the institutions (under the auspices of the Navy Board) with full time administrators responsible for building, arming, provisioning, maintaining, and manning the fleet.[63] N.A.M. Rodger notes that the creation of these institutions, although critical, cannot be viewed as a modern civil bureaucracy,

> "The new naval administration created at the close of Henry VIII's reign was strikingly more efficient and 'modern' than that of any other European state of the day (Venice and perhaps Portugal excepted), but it was not 'modern' at all in the way in which it integrated public and private business."[64]

All the critical appointments went to the competent ship owners, shipwrights, and mariners, who exchanged their expertise and service for the ability to profit from their post, as their official pay was nominal and often well in arears. However, we should not overlay modern standards of corruption or self-dealing on these men. Medieval England lacked an insulated civil service, but in these arrangements, one can glimpse the emergence of the mechanics of the modern bureaucratic state. Most important, for the era, these proto-bureaucracies proved remarkably efficient at building, manning, and provisioning a fleet. During Henry's reign, dockyards, shipyards, and foundries were built or expanded. Even though the English navy would have to rely on armed merchant auxiliaries and privateers well into the seventeenth century, the new

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[62] Rodger, *Safeguard*, 389, places this cost ratio at 4 to 1, well into the seventeenth century.

[63] Waters, 103, "As early as 1540 Henry VIII had framed a Navigation Act 'For the maintenance of the navy of England …' whose preamble admirably sets forth the case for the advancement of navigation." - cites 32 Henry VIII cap. 14 (1540) [(Navigation) c. 14. An Act for Maintenance of the Navy of England, and for certain Rates of Freights.]. He notes that it is reprinted in full in Hunter, H.C., *How England got its Merchant Marine* (1935).

Rodger, *Safeguard*, 221, adds that "The creation of this naval administration is the single most important achievement of sixteenth-century England in relation to sea power."

[64] Rodger, *Safeguard*, 226, he adds 233, that "The Navy and Ordnance Boards both represented a remarkable and sudden advance in the efficiency and sophistication of administration."

Navy Royal would provide the Tudor and Stuart monarchs with a core force upon which to center England's defense and an institutional apparatus to guide technological development.

This navy took another major technological leap during the reign of Henry VIII's daughter by Queen Katherine of Aragon, Edward VI's successor, Mary (r. 1553-1558). During her short and tumultuous reign, the Catholic Queen was responsible, through her marital alliance with Philip II, for introducing the cutting edge warship design of the day to the English navy. The Spanish galleon, smaller and longer in relation to its beam than the carrack, faster and better gunned, was the state of the art sailing technology in the early sixteenth century. Mary built three of these in England with Spanish guidance. That these ships became the prototype from which Sir John Hawkins built the even smaller, faster, more seaworthy, and better gunned Elizabethan 'race-built galleons' that were so instrumental in the defeat of Philip's Armada of 1588 and numerous piratical exploits of the era is another of history's strange ironies.

However, the Tudor monarchs and their councilors were not able to adopt the entire Iberian cosmological and maritime canon so easily. As Spain's chief cosmographer on the Council of the Indies, Andrés García de Céspedes, acknowledged at the time, the use of bearing and distance portolan chart navigation was still preferred in the Mediterranean and much of northern Europe despite the spectacular advances attributable to celestial navigation.[65] English seamanship was antiquated and outmatched by the Italians, French, Spanish, and Portuguese.[66] As a result, their trade opportunities were slight and the risks to their ships and crews were greater than those facing their competitors. English merchants would need to hire Sebastian

[65] Portuondo, 285.
[66] Waters, 82, "The French had quickly mastered the art of navigation as practiced by the Portuguese and Spaniards. As is evident from the early rutters, they had always been the link between the mariner of the Mediterranean and the North. They would soon be called upon to aid the English."

Cabot to train a new generation of mariners in celestial navigation, before England could claim anything resembling professional parity with Iberian or Breton seamen in the Atlantic.

Sebastian Cabot – Bridging Two Cultures

Iberia's lead in navigation in the fifteenth century was directly challenged from the north in the sixteenth. The first manifestation of this challenge came in the forms of imitation and piracy. This imitation did not happen randomly or sporadically. Rather there were a number of influential people in England who both recognized the dramatic possibilities presented by astronomical navigation and the riches that could flow from its adoption. Fortunately for the future of English maritime interests, these men included both the highest officers of the Tudor state or men who could claim them as patrons. England's Lord High Admiral, Lord Lisle (John Dudley) was an avid supporter of French astronomical cosmographers and Sandman and Ash contend that it was likely that he prevailed upon Edward VI's Privy Council to actively seek out Cabot.[67] Waters goes further, asserting that "it seems clear that Lord Lisle, the Lord High Admiral, was the power behind Cabot."[68] The future Elizabeth I's Secretary of State, Sir Francis Walsingham, himself a strong proponent of sea-borne empire, would sponsor the younger Richard Hakluyt, one of Tudor England's most vocal proponents and propagandist for enhancing England's maritime capabilities.[69] As Sandman and Ash note, Hakluyt urged England to

[67] Sandman and Ash, 830. They cite Cabot's return and subsequent inactivity in Bristol when Lisle lost office in 1547 upon Henry VIII's death. Lisle's reinstatement in 1549 coincided with Cabot's return to London.
[68] Waters, 84.
[69] Taylor, E.G.R., *Late Tudor and Early Stuart Geography 1583-1650: A Sequel to Tudor Geography, 1485-1583,* 15-16, illustrates how men of this era both acknowledged and thanked their high positioned patrons. She notes that "The Epistle Dedicatory to Sir Francis Walsingham sufficiently illustrates Hakluyt's charm and skill as a writer, and also displays his tact. … Finally the zeal of Walsingham for navigation is praised, and the encouragement that he has given to Hakluyt, both in regard to his past and present writings, is gratefully acknowledged, while the period is rounded off by a reference to the happy censorship of the Voyages by Dr. James, the Queen's Physician, under Walsingham's direction."

> "follow Spain's example, particularly in offering formal instruction in both the theory and practice of navigation. … Hakluyt believed that adopting Spain's approach of supplementing maritime experience with cosmographical instruction would encourage English sea captains to link theory with practice, leading to 'almost incredible results.'"[70]

Hakluyt and others went even further in pitching the adoption of Spain's navigation process. Jack Beeching, notes in his introduction to Hakluyt's *Voyages and Discoveries*, Bacon's observation in the *Advancement of Learning*, "This proficience [sic] in navigation and discoveries may plant also an expectation of the further proficience [sic] and augmentation of all sciences."[71] This belief in generating national prosperity and acumen from maritime skill was advocated earlier in the century by Dr. John Dee. He overtly connected navigational prowess and national power and was determined to help England close this particular knowledge gap through both study and subterfuge. A prolific writer on mathematics, astronomy, navigation, and ship building, the early Dee was able to identify critical errors like that of Peter Perigrinus who assured English mariners that the compass needle turned to the celestial pole rather than the magnetic pole.[72] He would rewrite the canonical navigation books of the Muscovy Company in the middle of the sixteenth century that were first written by Robert Recorde.[73] Dee also advocated using signaling mirrors for controlling coastal defense vessels and for the adoption of naval telescopes long before their invention.[74] Dee was at the forefront of introducing science to

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[70] Sandman and Ash, 813-814. The authors quote the Epistle Dedicatory to Sir Walter Raleigh in *De Orbe novo Petri Martyris … Decades octo*, Paris 1587 (Translation by F. C. Francis, in *The Original Writings and Correspondence of the two Richard Hakluyts*. Vol. 2, pp. 366-7, Hakluyt Society, Ser. 2, vol. 77.) In this epistle, Haklut is praising Raleigh's decision to use the mathematician Thomas Harriot to both solve navigational problems and train his sea captains. From Waters, Appendix No. 16 C, 546.

[71] Hakluyt, Richard, *Voyages and Discoveries*: *The Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation*, edited, abridged, and introduced by Jack Beeching, 12.

[72] Deacon, 28, cites, E.G.R. Taylor, *Tudor Geography: 1485-1583.*

[73] Baldwin, Robert, "John Dee's Interest in the Application of Natural Science, Mathematics and Law to English Naval Affairs," in *John Dee: Interdisciplinary Studies in English Renaissance Thought; Volume 193 of International Archives of the History of Ideas*, edited by Stephen Clucas, 99, "Dee's navigational teaching had initially followed the largely mathematical syllabus taught in London from 1547 by a fellow Welshman, Robert Recorde. From 1560 onwards Dee set about correcting some of Recorde's textbooks for re-issue after Recorde's death in 1558 because those texts were used to instruct the Muscovy Company's pilots."

[74] Deacon, 81.

direct Elizabeth's mariners. This link between early science and English navigation would grow stronger as the seventeenth century progressed and we will return to the topic and Dr. Dee in the following chapters. But to get their oceanic project started and to quickly catch up with decades of Iberian maritime advances, the English maritime advocates needed Cabot's expertise.

Lord Lisle and the Muscovy Company merchants succeeded in hiring Sebastian Cabot, who after thirty years as the pilot major of Spain's *Casa de la Contratación,* would serve as the conduit for this transfer of expertise.[75] Ironically, as Sandman and Ash note, Spain had previously hired Cabot in 1512 away from his English service to exploit his (and English) "knowledge of the 'codfish island' frequented by English fishermen (probably Newfoundland), and of the navigation to the Indies."[76] Like his father before him, the younger Cabot was employed by Henry VII, and even received a royal pension in 1505 at the age of 21.[77] He continued his father's quest for a Northwest Passage with his own voyage in 1508. In 1512 he participated in an English diplomatic mission to Spain (early in the reign of Henry VIII to press Tudor feudal claims in France), which indirectly resulted in his Spanish job offer and his almost thirty year tenure as the Casa's Pilot Major. In this role, Sandman and Ash note, that although he was a knowledgeable and practicing astronomical navigator in the Iberian fashion, he was also a deep believer in the importance of practical seamanship and soon became a champion, not of metropolitan cosmographer controlled astronomical navigation, but rather of practicing pilots. This added one more ironic twist to Cabot's story; in Spain he had championed the practical skill of the pilots as superior to the theory based cosmography that his English patrons were hiring

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[75] Sandman and Ash, 813-815.
Ash, Eric, *Power, Knowledge, and Expertise in Elizabethan England*, 103-113.
[76] Sandman and Ash, 817.
[77] Waters, 80-81, notes that "It was Henry VII who made the naval interests of the English for the first time part of a deliberate, settled policy. … Henry VII had to be content to build up the traditional home trade between Portugal, Spain, France, and the Netherlands and to seek to establish new European markets in the Baltic and the Levant. … He built up a modest 'narrow seas' navy of ships able to guard his shores and convoy his merchants' ships in troublous times safely along the routes between the North Sea and Biscay ports."

him to impose upon their company pilots. Sandman and Ash observe that this was in large part due to the fact that "the English perception of Spanish navigational training was actually an idealized distortion, bearing little resemblance to the internal strife that often characterized the *Casa de la Contratación* during the sixteenth century."[78] Like most modern bureaucracies, the Casa was rife with infighting between advocates of new policies and entrenched interests representing past practice and experience. Even though astronomical navigation had produced staggeringly successful results, its detractors, especially in the sixteenth century, could point to its uselessness in inclement weather and to the large inaccuracies generated by the primitive state of instrument technology and human error. Like many new technologies still in development, the promise of the new often exceeds the first results, and only dedicated advocates can see past initial limitations to their eventual resolution.

Although Cabot was the pilot's champion in the Casa, he was on the losing end of the struggle for primacy between the generators and users of cosmographical knowledge in Spain. His own unsuccessful voyage of exploration on Spain's behalf to East Asia ended miserably in Brazil, caused his fall from grace and despite his later reinstatement, aided the advocates of theory dominated cosmographical practice in the Casa to triumph.[79] Despite this loss, his departure from Spanish service was amicable and his European cosmographical reputation sound

[78] Sandman and Ash, 814-819. Cabot was central to this strife which featured the metropolitan theoreticians, the declination table and chart making cosmographers on one side, and the practical users, the seagoing pilots, represented by Cabot, on the other. The pilots needed the charts and declination tables to use the advances of astronomical navigation on their voyages, but the cosmographers needed the pilots to record and observe data throughout their journeys. The author's story is one of long dispute centering upon whose knowledge and whose priorities would be privileged.

[79] Ibid, 823, note the Cabot-Cosmographer debate found material basis in the types of charts used. Since cosmographer charts had errors which did not account for magnetic variation, the pilots preferred their compass bearing portolan charts as holding more weight than the new astronomically generated charts, even though they used both in tandem. This debate of precedence and priority of knowledge was won by the cosmographers in the end. The author's note that "Despite petitions from the pilots and advice from various Casa officials, the Council of the Indies sided with [Cabot antagonist and cosmographic lecturer Alonso de] Chaves and [cosmographer Pedro] Medina. In 1545 they banned the type of chart promoted by Cabot and [Cabot appointed cosmographer Diego] Gutiérrez and preferred by the pilots." This bureaucratic victory was decided less upon technical merit, but rather upon political efficacy in producing charts that would stymie Portugal's territorial claims.

enough to make his prospective employment a coupe for his new English benefactors. They had either no interest in or knowledge of his disputes in the Casa. He was hired specifically to teach the English the cosmographic knowledge, the primacy of which he had opposed.

When back in London, Cabot organized the 1550-1551 Levant journey of bark *Aucher* and the follow-up journey of the *Lion of London* to Barbary. These two voyages were essentially training missions for English seamen in conducting long distance trade.[80] Both journeys were profitable and the Barbary mission inspired follow-up journeys to Western Africa. In his *Voyages and Discoveries*, Hakluyt presents us with edited logs of the *Aucher's* captain, Roger Bodenham. The voyage was by no means easy; Bodenham had to deal with hostile Turks and rebellious mariners, and his return to England was a close run thing. Of significant note is his reliance on a Spanish pilot, whose assistance was crucial in the Mediterranean,

> "I had in my shippe a Spanish pilot called Noblezia, which I tooke in at Cades [Cadiz] at my comming foorth: he went with me all this voyage into the Leuant without wages, of good will that he bare me and the shippe, he stoode me in good steede vntill I came backe againe to Cades, and then I needed no Pilot."[81]

Bodenheim could rely upon an English pilot in the familiar waters of the Channel and the Northeast Atlantic, "The master of my ship was one William Sherwood. … I had prouided a skilfull pylot to cary me ouer the lands end, whose name was M. Wood."[82] However, in a pattern which echoes da Gama in the Indian Ocean, and as we shall see, Drake in the Caribbean and Pacific, local experts with specific hydrographical knowledge were indispensable ingredients in the growing European diaspora across the world's oceans.[83]

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[80] Sandman and Ash, 831, note that "*Aucher* apparently served as a sort of maritime clinic for the inexperienced Englishmen who sailed in her."
[81] Hakluyt, *THE SECOND VOLVME OF THE principall Nauigations, Voyages, Traffiques, and Discoueries of the English nation, made to the South and Southeast quarters of the world, within the Straight of Gibraltar, with the Directions, Letters, Priuiledges, Discourses, and Obseruations incident to the same*. 100.
[82] Hakluyt, *principall Nauigations* vol. II, 100.
[83] Waters, 79, notes that the few pre-Cabot Atlantic voyages of English West Country men like the elder Hawkins followed this pattern as well. "In the 1530s old William Hawkins of Plymouth and a few others had voyaged to

Hakluyt's Bodenham also makes particular mention of the mariners that accompanied him who within half a decade would be capable of captaining their own voyages, and he calls out two specifically who would gain their own prominence in England's maritime saga.

> "And all those Mariners that were in my sayd shippe, which were, besides boyes, threescore and tenne, for the most part were within fiue or sixe yeeres after, able to take charge, and did. Richard Chanceller, who first discouered Russia, was with me in that voyage, and Mathew Baker, who afterward became the Queenes Maiesties chiefe ship-wright."[84]

Hakluyt wants his audience to understand, that these early Cabot directed journeys were essential first steps in developing England's maritime tradition.

However, Cabot's most significant contribution to England's maritime legacy was his pivotal role in organizing, as Sandman and Ash note, "England's first incorporated joint-stock trading enterprise, commonly known as the Muscovy Company."[85] The rationale for pooling resources and sharing risks was presented again by Hakluyt,

> "Seeing that the wealth of the Spaniards and Portuguese, by the discovery and search of new trade routes and countries was marvelously increased, supposing the same to be a course and mean for them also to obtain the like, they themselves resolved upon a new and strange navigation."[86]

Avarice and imitation were of course not new, but this proto-modern device, the joint-stock company was groundbreaking. Unlike the government sponsored Iberian Atlantic oceanic enterprises, England's merchants and notables had to devise a funding mechanism which the cash strapped Tudor monarchs either could not, or would not provide. The idea of pooling risks and rewards has earlier historical precedence, as did the use of private capital for achieving

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Brazil and brought back dye-wood, but it seems certain that they all engaged foreign pilots to take them there and that the French wars put an end to their activities."

Waters, 89-90, also notes that English successor missions to the Guinea coast were made possible by a pair of Portuguese pilots who had defected to English service named Anthony Pinteado and Francisco Rodrigues. They revealed the closely held Portuguese knowledge, generated by decades of dangerous caravel voyages, of the wind patterns off that coast to the English.

[84] Hakluyt, *principall Nauigations* vol. II, 101.
[85] Sandman and Ash, 832.
[86] Hakluyt, *Voyages and Discoveries*, 60.

national objectives, as we have seen with the Dutch. However this joint-stock format and its peculiar legal mechanisms, many of which survive today were distinctly new. The English East India Company (1600) and its Dutch competitor (the United East Indian Company – *Vereenigde Oost-Indische Compagnie* – or VOC of 1602) were structural descendants of Cabot's Muscovy Company.[87] These mercantilist and quasi-capitalist entities relied upon royal charters and monopoly trading rights to vouchsafe their initial investments, but their structure of including limited liability and diversified ownership apportioned through negotiable stock certificates endures, as does the industry created to trade in these securities.

The structure and risk diversification strategy of the Muscovy Company was not its only innovation. Cabot's direction of that company as 'governor-for-life' and in particular, his direction of trading expeditions, would set the pattern for future English maritime practice. Beeching has noted that "Organized [English] mercantile exploration may be said to have begun in earnest in 1553, with Sebastian Cabot's instructions to Sir Hugh Willoughby, whose expedition, though intended for Cathay, pioneered the northward route to Russia."[88] These '*Ordinances for the direction of the intended voyage for Cathay*' addressed basic unity of command, fleet safety, health, and welfare issues sorely lacking on earlier English merchant ventures. Beeching concludes that "Cabot's set of imperatives for shipboard life, derived from Spanish experience, were to serve the English well for the next four centuries."[89]

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[87] Waters, 88, when assessing the impact of the early Muscovy Company notes that "the commercial organization. The joint-stock company, created to finance the trade that arose from the [Artic] discoveries, proved so sound that it was adopted with equal success as a means of financing later trading, colonizing, and raiding ventures otherwise quite beyond the means of individual merchants or captains or even the Government."
[88] Beeching, 11.
[89] Ibid.

Cabot also established among the English the need to meticulously gather data. This included ethnographic and economic data. In his twenty-seventh and twenty-eighth items he directs his people to record,

> "the names of the people of every Island, are to be taken in writing, with the commodities, and incommodities of the same, their natures, qualities, and dispositions, the site of the same, and what things they are most desirous of, & what commodities they wil most willingly depart with, & what mettals they have in hils, mountaines, streames, or rivers, in, or under the earth.
>
> if people shal appeare gathering of stones, gold, mettall, or other like, on the sand, your pinnesses may drawe nigh, marking what things they gather, using or playing upon the drumme, or such other instruments, as may allure them to harkening, to fantasie, or desire to see, and heare your instruments and voyces, but keepe you out of danger, and shewe to them no poynt or signe of rigour and hostilitie"[90]

Cabot also stressed the need for his captains and pilots to gather and chart extensive hydrographical, navigational, and astronomical data points in the fashion demanded by Spain's cosmographer dominated Casa. In his seventh item, Cabot directed,

> "that the marchants, and other skilful persons in writing, shal daily write, describe, and put in memorie the Navigation of every day and night, with the points, and observation of the lands, tides, elements, altitude of the sunne, course of the moon and starres, and the same so noted by the order of the Master and pilot of every ship to be put in writing, the captaine generall assembling the masters together once every weeke (if winde and weather shal serve) to conferre all the observations, and notes of the said ships, to the intent it may appeare wherein the notes do agree, and wherein they dissent, and upon good debatement, deliberation, and conclusion determined, to put the same into a common leger, to remain of record for the company: the like order to be kept in proportioning of the Cardes, Astrolabes, and other instruments prepared for the voyage, at the charge of the companie."[91]

This direction would enable England to start compiling its own geographical and navigational canon, which in turn would make repeat journeys and established trade routes possible.[92] Merchant captains, pirates, and Royal officers alike, were now being knit together in an institutional drive to acquire, reconcile, and disseminate navigational knowledge. The maritime

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[90] Hakluyt, *Voyages and Discoveries*, 58.
[91] Ibid, 56.
[92] Waters, 90, observes that "here were the essentials for subsequent successful voyages over the same route. So sound were they that they became an integral part of every subsequent English voyage of repute."

enterprise was growing bigger than any captain, pilot, company, or navy. Success required a bureaucracy on the Spanish model, at least in regard to gathering and organizing inputs from multiple sources, and then reproducing consensus data in a form useable by sailors at sea.

Sandman and Ash note the English Cabot could not champion experienced pilots in debates with theoretical cosmographers as he had done at the Casa. There were no experienced oceanic pilots in English service and he was the cosmographical authority in England.[93] Being a *tabula rasa*, the English maritime establishment provided Cabot with the conditions to create the Spanish navigation system idealized by those not involved in its daily intrigues and feuds. One of Cabot's protégés would be critical in importing the balance of this idealized cosmographic system to England in the years following Cabot's death in 1557. Stephen Borough had accompanied Richard Chancellor on the first Muscovy expedition. Within three years Cabot gave him an expedition of his own to command. Although Cabot did not live to see Borough's return, the latter's influence on Tudor maritime development would be second only to that of the 'Father of English Navigation' himself.

The Muscovy expeditions obviously failed in their primary objective of finding a Northeast Passage to Cathay. The voyages were arduous and cost many ships and lives, including that of Sir Hugh Willoughby on the first expedition and eventually that of Richard Chancellor in 1556. However, Chancellor and Borough were able to pioneer a northern route to Russia and England established diplomatic relations with the Czar's court. Waters notes that this trade route, although not as lucrative as the eastern spice trade, provided England with a

[93] Sandman and Ash, 838, "Cabot chose to emphasize celestial navigation, not only because of his ambitions as a learned cosmographer, but more importantly because it could serve as a vital supplement to the limited knowledge of inexperienced pilots, since astronomical methods could be taught relatively quickly without requiring long years at sea."

desperately needed alternative source of maritime stores.[94] Equally as important to English maritime interests was the fact that these expeditions and Cabot's training, provided the Tudors with a generation of experienced navigators trained in Iberian astronomical techniques, but also ones that were rapidly becoming the local experts in high latitude sailing and navigational pioneers in their own right.[95] The belated and quick apprenticeship period of English seamanship fostered by Cabot was coming to an end. English seamen were ready to leave their harsh Arctic nursery and challenge Spain and Portugal in the Atlantic.

Map 5.3. The route of Sir Hugh Willoughby's and Richard Chancellor's first Muscovy Expedition (below).[96] This route proved extremely hazardous but established trade and diplomatic relations between England and Russia.

[94] Waters, 88, notes "The immediate gains were important. The principal Russian products were naval stores – pitch, hemp, and timber. Hitherto these had come from the Baltic through the medium of the Hanse League, who could thus control the English navy and merchant marine. The Russian trade broke this monopoly."
[95] Ibid, "Modest as the success of the Cathay venture was, it was of prime importance in the development of English maritime enterprise and navigational skill."
[96] Mitchel, Mary Ames, "1553 Looking for a Passage to Muscovy," Beforewinthrop.com, http://beforewinthrop.com/section2/BW2-05-1553-Muscovy.html.

Figure 5.3. The emergence of joint stock companies. Sebastian Cabot (1474-1557)(left), the 'Father of English Navigation' presented here as an elderly cosmographer with globe and dividers, was the first governor of England's first joint stock company and the author of its general policies.[97] His Muscovy Company Seal (lower right) is depicted emblazoned with the company motto, *Refugium Nostrum in Deo Est* ("Our Refuge is in God").[98] The ship is sailing towards the sinister, signifying 'The East.' The company inspired immitation and evolution. The more successful Dutch joint stock venture and its innovation of issuing stock certificates is depicted above.[99] Heralded as the first stock certificate ever issued, a 1606 Share Of The Dutch East India Company (VOC) is in the upper right.

[97] Engraving of the navigator and cartographer Sebastian Cabot (1474 - 1557), after an original by Hans Holbein [or the original may perhaps have been a close copy], that was destroyed by fire in 1845. A version of the engraving was published in vol. 2 of Samuel Seyer, *Memoirs historical and topographical of Bristol and it's neighbourhood; from the earliest period down to the present time*, printed in Bristol by John Mathew Gutch, 1823 (Internet Archive). This scan, which has a slightly different caption, is from the website of the National Maritime Museum, Wikipedia.org, https://en.wikipedia.org/wiki/Sebastian_Cabot_(explorer)#/media/File:Sebastian_Cabot_-_S._Rawle_after_Hans_Holbein,_1824.jpeg.
[98] "Muscovy Company," Wikipedia.org, https://en.wikipedia.org/wiki/Muscovy_Company.
[99] Activemarkettrading.com, http://www.activemarkettrading.com/wp-content/uploads/2014/05/Dutch-East-India-Company.png.

Protestant Imitation, Innovation, and Piracy

As we have discussed, eventually, the more literate English navigators adopted the Spaniard Martin Cortés's 1551 navigation manual.[100] Steven Borough, one of Sebastian Cabot's protégés and an avid explorer for the Muscovy Company, took advantage of the brief Catholic marital alliance between the Spanish and English monarchs, to both train and lecture at the *Casa de Contratación* in Seville in 1558. [101] He brought Cortés's manual back with him in 1560 and had Richard Eden publish it in English.[102] However, the English did not produce one of their own until William Bourne published his *A Regiment for the Sea* in 1574. Borough did much more for English maritime development than explore the Northeast Passage and pilfer Spanish navigation texts.[103] Sandman and Ash note that he advocated for "the appointment of an English pilot major [on the Spanish model] … [to] bring England into line with common practice in 'Spaigne, Portingale, and other place[s] wheras Navigacon florishethe.'" [104] He used his considerable renown and connections to vociferously advocate for changing the English seagoing culture.

[100] Portuondo, 52.

[101] Ash, 117, notes in addition, "Queen Mary's marriage to King Philip II of Spain in 1554 had cemented Anglo-Spanish relations to the point where [Stephen] Borough was welcomed at the *Casa de Contratación* in Seville as an esteemed guest."

Waters, 103, notes the same monumental benefit from this short-lived Anglo-Spanish marital alliance. "One inestimable gain the English had won from the Spanish marriage was this: in 1558 Stephen Borough, who had succeeded Richard Chancellor as Chief Pilot of the Muscovy Company, had been admitted to the Casa de Contratación at Seville as an honored guest."

Rodger, *Safeguard*, 305, notes that "Prince Phillip [later Phillip II] anxious to improve the capabilities of his wife's [Mary Tudor] subjects, sent Stephen Borough in 1558 to study at the navigation school maintained by the Casa de Contratación in Seville. He brought back the standard Spanish textbook, Martin Cortés's *Arte de Navegar*, which was at once translated into English."

[102] Sandman and Ash, 841.

[103] Ash, 116, notes that "Stephen Borough helped to transform the trip to the White Sea from a voyage of exploration into a normalized trade route."

[104] Sandman and Ash, 814.

Stephen Borough presented Queen Elizabeth's Privy Council with three compelling reasons to imitate the Iberian navigation training and licensing program as embodied in the *Casa de la Contratación* and more specifically in the office of pilot major.

> "The first is it gevithe occasion to make perfect mariners wheras otherwise the navigantes shold haue remained in their accustomed iggnorauncye.
> The second that throughe their excelencye in navigacion greate benefyte honor and fame redoundeth to their country.
> The third ys that they haue no losses of shippes or shipwrecke through ignoraunce of mariner craft as in other countries where the same wanteth it chauncethe."[105]

His tripartite argument for institutionalizing England's maritime resources was that it was necessary in order to create astronomical navigators, who thereby would enhance the wealth and prestige of the nation, and have the added benefit of preserving ships and crews at sea. The substance of Borough's petition, had earlier found its first receptive audience, not in the high councils of state, but with London's merchants. Borough wanted to establish for the entire English maritime establishment, what the Muscovy Company had accomplished under Cabot.

Borough wanted all *new* navigators ("not of the olde and approvid good masters and marinors, but suche as dayly of youthe springeth vpp") trained, examined, and licensed by the new pilot major. This training would allow them to survive the sea and excel in trade, thereby bringing "habundaunce of Riches and cummoditie … into their cuntry." Borough was clever not to offend the sensibilities of the established maritime establishment and its senior practitioners. Instead he made his pitch for the future of the trade and the licensing of its newest members.

The navigator he believed appropriate for the post of England's pilot major was someone in the mold of "the good olde and famuse man master Sebastian Cabola, and also pilottes out of Fraunce for the gemmye [Guinea] viages etca." He wanted England to appoint a 'Cabot' (both an explorer and a theoretical cosmographer) to short cut England's apprenticeship in

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[105] Borough, Stephen, "Petition for the Creation of the Office of 'Pilott Maior'," B.M. Lansdowne MS. 116, ff. 6 and 7 [1562]. From Waters, Appendix No. 6 A, 513-514.

astronomical navigation and he was specific about what he expected his nation's mariners to learn,

> "the arte which is to know the latitude of the sonne or stares, the variacion of the cumpas, with diuers [diverse] other sundry rules and waies wherby they knowe and reakon their shippes waies exactly althoughe the sonne and stares be hid longe from them, and not be seene."[106]

In short he wanted mariners versed in the astronomical navigation techniques pioneered in Iberia, but also seasoned mariners with experience in dead reckoning and compass bearing navigation for inclement weather ("the olde Auncient rules"). He was aware that experience would only come with time and apprenticeship at sea. Again, he wanted the combination of cosmographic theory and experienced seamanship that resided in men like Sebastian Cabot.

Borough followed up his petition, with his own draft appointment as "Cheyffe Pylott of this our realme of Englande" to Elizabeth I. He asked for the authority to license all pilots and masters sailing any ships of England. Additionally, he requested the authority to license "Boatswayne, quarter master, or masters mates" and certify their soundness as mariners.[107] Borough wanted to replace the limited seniority system of the English system with a graduated hierarchy based upon skill and compensated accordingly.[108] Borough was appointed one of four masters to all English ships in the Medway (Kentish riverine port at the mouth of the Thames estuary); he served until his death in 1584.[109] In this role he was able to extend Cabot's Spanish

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[106] Borough, "Petition."
[107] Borough, Stephen, "Cheyffe Pylott of this our realme of Englande," B.M. Lansdowne MS. 116, ff. 4 and 5 [?1563-Jan. 1564]. Boatswains or bosons were petty officers who directed the labors of sailors aboard ship in regard to rigging, anchors, and cables; quartermasters were helmsmen, they assisted the master of the vessel by steering the ship – usually from the quarter deck; and master's mates assisted the master in running the ship, navigating, and plotting the ship's course.
[108] Waters, 104.
[109] Ibid, 106-107, in denying Boroughs the office of Chief Pilot, the Privy Council decided to emulate Spanish navigational training without the centralized bureaucracy of the Casa. They adapted their existing institutions, primarily the Trinity Houses from who, Waters reasonably argues, derived the chief opposition to Borough's appointment as Chief Pilot, as such an office would conflict with the original responsibilities granted to Trinity House (Deptford Strand) by Henry VIII in 1514 and reaffirmed by Elizabeth upon her ascension in 1558.

apprenticeship to a broader selection of Tudor seamen.[110] However, he still used Eden's translation of Cortés's manual as his guide. It would take another Englishman to produce not just a translation of Spanish navigational practice, but a logical fruition to the century old Iberian project of codifying and systematizing the process of astronomical navigation. This author, William Bourne, would also make the newest advances in the maritime profession accessible to a wider selection of common sailors.

William Bourne and *A Regiment for the Sea*

William Bourne was critical of Cortés' manual specifically with regard to its efficacy for common English mariners.[111] He accelerated the Iberian process of simplifying practical astronomy for the educated and trained pilot, by further simplifying latitude determination for English seamen with little to no formal education. Bob Graham has presented a comparison of the work required of the respective Spanish and English pilots using as their guide Cortés and Bourne respectively. The Spanish pilot would require three tables, some complicated mathematics, knowledge of the zodiac, and almost a dozen steps to get the same answer Bourne calculated for the English seaman in his single chart. Bourne, a self-taught mathematician of common birth himself was invading the academic sphere of university educated gentlemen by publishing a book in English aimed not at educated gentlemen, but at practicing seamen. Taylor notes that in order to avoid confrontation with this class, Bourne had to efface himself and declare that "his books were not intended for the 'learned sort'. They were meant only for

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[110] Waters, 496, "It was the Spanish system, as interpreted for them by Sebastian Cabot in the 1550s, and by Stephen Borough in the opening years of Elizabeth's reign, and as modified by the Privy Council to suit the English temperament and institutions, that lay behind the chartered trading companies, of which the Muscovy Company was the first to foster navigation, and behind the legislation of the 1560s, which ensured a sufficiency of seamen and, through Trinity House, of licensed masters, to serve the country in either peace or war. It was the Spanish system which provided the English with their first manual of navigation, … [and] which inspired the lectureships on navigation that were eventually established."

[111] Taylor, *A Regiment for the Sea and Other Writings*, xxvi, and 7, in Bourne's opinion, "it was too difficult a book for the English apprentice to the sea."

'meaner men' to read, men who at present were utterly ignorant."[112] In addition to providing nautical rules and calendar data, Bourne reduced the arduous task of determining daily solar declination as he states:

> "Therefore, I thought it convenient to calculate these tables following, and the first rowe towards your left hand be the daies of the moneth, the next be the degrees of declination, and the thirde, the odde minute belonging to declination."[113]

This targeting not of scholars, nor even metropole trained and licensed pilots, but rather the large community of common sailors through simplicity set this English manual apart from its Iberian predecessors. The English maritime adventure would be something new, and it would require the participation of a larger more socially diverse maritime community. Bourne echoed this sentiment in the dedication to Lord Clinton, the First Lord of the Admiralty, in his 1574 printing of *A Regiment for the Sea*, "I being of all other most simple yet notwithstanding this enterprise have I taken in hande, to publishe this simple booke unto all men."[114]

When far from London and the North Atlantic, all these tables would need to be interpreted again for longitude and unfortunately, determining longitude at sea continued to be the elusive holy grail of early modern navigation science. Bearings at sea needed to be adjusted for magnetic variation and dip. Calculating ship speed and distance traveled in concordance with leeway and current would demand more refined technological solutions and mathematics. Instrument manufacture would require more precision. The complicated mathematics of spherical trigonometry would require simpler heuristics and the invention of logarithms for quick resolution in a hostile element. England would over the next century dedicate its resources and

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[112] Ibid, xiii, notes as well that Bourne was "neither a scholar nor of gentle birth, he intruded into the field of authorship which was still generally regarded as the preserve of the scholar and the gentlemen." Xxxiv, Taylor adds that "These self-educated men had, indeed, an advantage over those schooled in the classics in that they enjoyed a freshness of outlook and a readiness to speculate unchecked by an inculcated reverence for authority."
[113] Bourne, William, *An Almanacke of Three Yeares, 1571*, the sixth rule, 73.
[114] Bourne, William, *A Regiment for the Sea, (1574)*, dedication, 137.

best minds to attacking problems like these and would develop university lectureships and state institutions targeted at growing its seaborne resources. The late Tudor state was modernizing its institutions and its maritime infrastructure at the same time. We will address these concomitant developments and their agents in the next chapters.

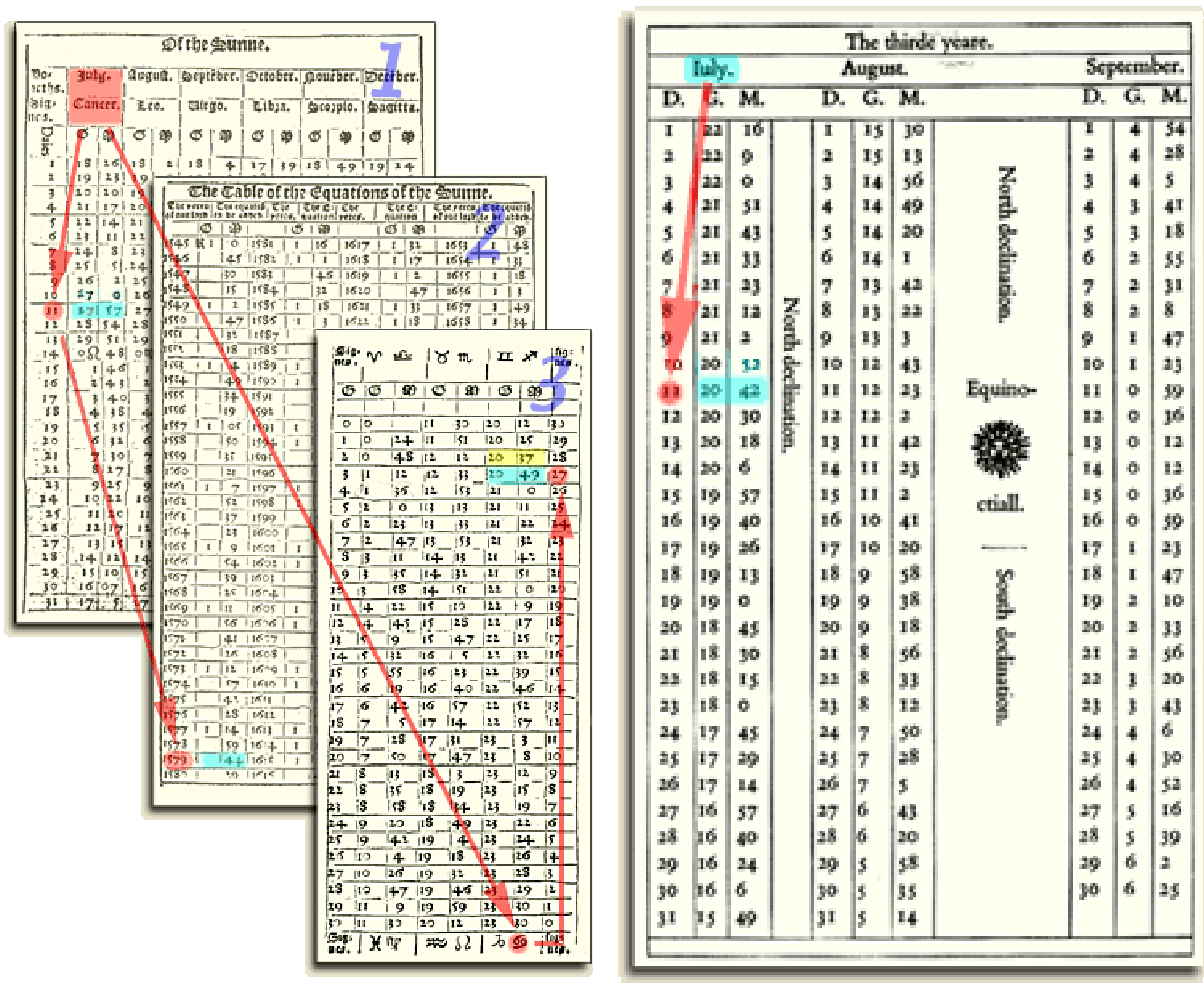
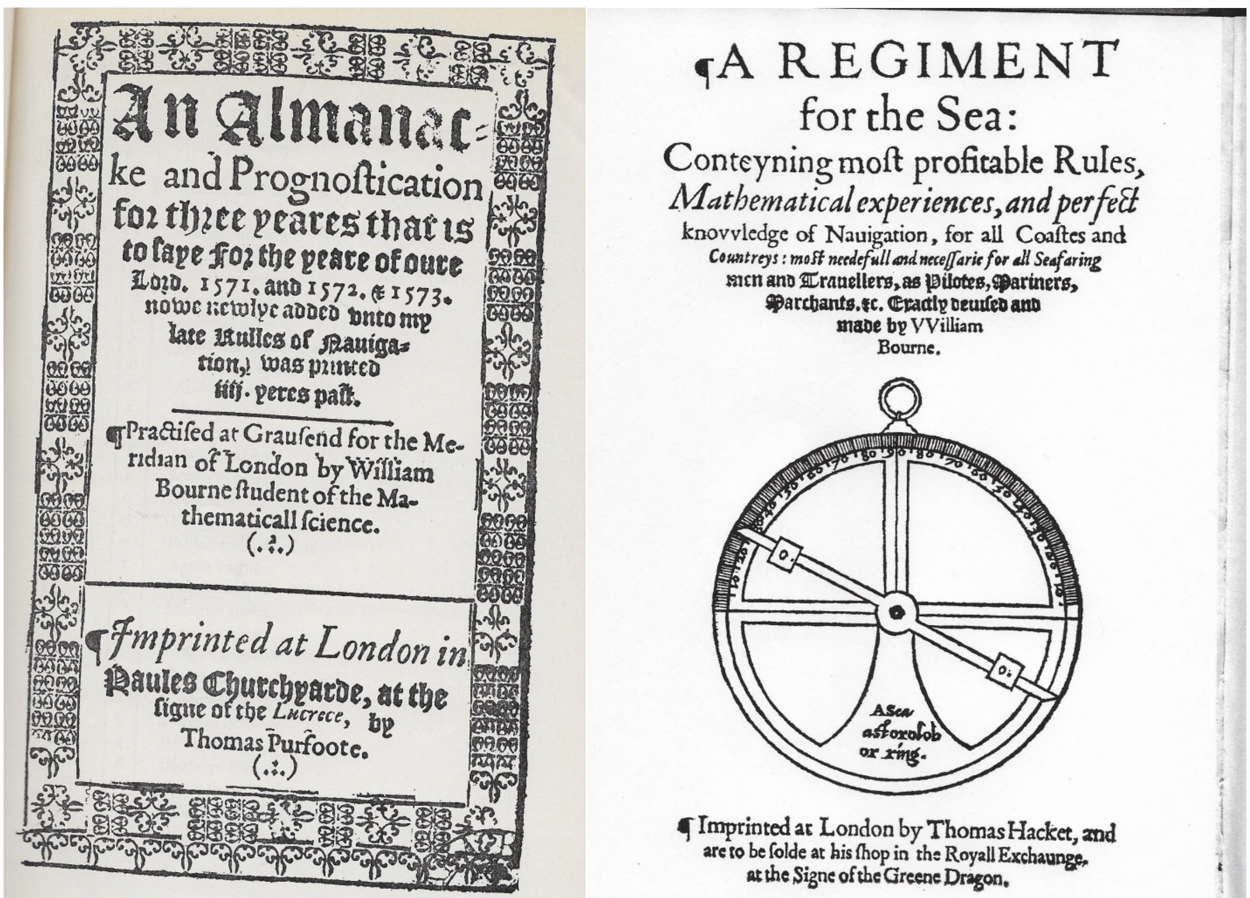


Figure 5.4. ***The Regiment for the Sea*** **'Black Box'** – William Bourne broadened the reach of his navigation manual by tabulating the calculations required by Cortés. In Bob Graham's example presented above, the Spanish pilot would (1) enter the date into table 1, July 11th; resulting in 27º57'. (2) In table 2, he enters 1579; yielding 00º44'. (3) He adds this to the first; 28º41'. (4) Non-leap year adjustment – subtract 1º00'; 27º41'. (5) 27º41' is true position of sun in Cancer entered into table 3 – the column with Cancer's symbol – 27º yields 20º49' – inexact. (6) Next degree 28 is 20º37' – interpolation required. (7) 00º12' difference. (8) 41'/60' past 27º is approximately 2/3. (9) 2/3 of 12' is 8'. (10) 8' subtracted from read for 27º; 20º49' less 8' equals **20º41'**. The English pilot enters July 11th on the proper year chart and reads **20º42'**.[115] Either pilot would take his reading of the Sun's altitude at noon above the horizon with a cross-staff or mariner's astrolabe (shooting the point of the sun's transit apex where it crosses the longitudinal meridian). He would subtract the declination calculated above. He would then subtract the resulting difference from 90º - the final result would be his current latitude.

[115] Graham, Bob, "A Comparison of Declination Tables," Longcamp.com, http://www.longcamp.com/cortes.html.

With the ascension of Elizabeth (1558), and the ensuing deterioration of Anglo-Spanish relations, the English could no longer count on the friendly transfer of navigational or ship building expertise. With sectarian rifts propelling Elizabeth and Philip II toward open war, England's maritime advocates would have to turn to other means to learn the rest of the Iberian maritime canon, and protect their discoveries and innovations from their erstwhile ally. In order to absorb the rest of Iberia's cosmographic and nautical canon, England would have to rely on theft, piracy, kidnapping, and its budding intelligence organizations. These efforts would be directed from the heart of Elizabeth's government, her Privy Council.


An Almanacke and Prognoſtication for three yeares that is to ſaye For the yeare of oure Lord. 1571, and 1572, & 1573. nowe newlye added unto my late Rulles of Nauigation, I was printed iiij. yeres paſt.

¶Practiſed at Grauſend for the Meridian of London by William Bourne ſtudent of the Mathematicall ſcience. (.∴.)

¶Imprinted at London in Paules Churchyarde, at the ſigne of the *Lucrece*, by Thomas Purfoote. (.∴.)

¶A REGIMENT for the Sea: Conteyning moſt profitable Rules, *Mathematical experiences, and perfect* knowvledge of Nauigation, for all Coaſtes and *Countreys: moſt needefull and neceſſarie for all Seafaring* men and Trauellers, as Pilotes, Mariners, Marchants, &c. Exactly deuiſed and made by VVilliam Bourne.

¶Imprinted at London by Thomas Hacket, and are to be ſolde at his ſhop in the Royall Exchaunge, at the Signe of the Greene Dragon.

Figure 5.5. William Bourne's *Almanac of Three Years* (1571 edition) and his *Regiment of the Sea* of 1574.[116]
These manuals derived and expanded for use by practical seamen in part from the *Arte de navigar* of Martín Cortés

[116] Bourne, William. *A Regiment for the Sea: Conteyning most profitable Rules, Mathematical experiences, and perfect knowledge of Navigation, for all Coastes and Countreys …* London: Thomas Hacket, 1574. Figure 1.

were presented to a much broader nautical audience. They simplified the Iberian method of determining daily solar declination and they and their many subsequent newer editions became the standard sailing manuals of Tudor England.

Connections

In this chapter we have examined the emergence of large complex Iberian maritime bureaucracies designed to centrally manage all aspects the emerging oceanic trade, the development of printed propaganda as a weapon of war and for swaying public opinion, and lastly the systematizing of complex technological endeavors for the use of men of little education for the directed purpose of state and corporate interests. All of these emerging trends are recognizable today as features of our modern world, and they all were at least partially initiated by the actors involved in running the Western European maritime programs, or as a result of the exigencies of the oceanic program and its ancillary wars. More significant than their ubiquity today, was their novelty in the sixteenth century. These institutions, forms of mass moral persuasion, and intellectual automation, were exigent improvisations by men embracing a new world, new technology, and new tasks. Their brilliance was not in their self-evident success as judged by the knowledge of future events which we easily predict in hindsight, but rather in their temporal efficacy. The directors of the maritime programs improvised, often failed, and re-tooled their devices for coping with and expanding the new technologies of the maritime canon. Their successfulness must first be gauged by their effectiveness in delivering the desired results of their directors. Some institutions, like the English navigation cannon or mass printed propaganda, like the ships themselves, evolved like the carrack into its technological successors. Other institutions like the *Casa de Contratación*, were efficacious for decades, but like the caravel, did not in the long run evolve into more effective platforms. Regardless, their import at

Compiled in *A Regiment for the Sea and Other Writings on Navigation By William Bourne of Gravesend, a Gunner (c.1535-1582),* edited by E.G.R. Taylor. Cambridge: Cambridge University Press for the Hakluyt Society, 1963.

the time, and their influence upon other sixteenth century evolving institutions and ship technology was critical, and those impacts had deep ancillary influences. Although some scholars claim that the Casa had ossified as a dynamic institution by the close of the sixteenth century, its obvious tutelary import to the new English institutions was immense.

Another proto-modern practice emerging from this period and the first war to break the Iberian lock on oceanic trade was the unfettered and aggressive use of private capital for national aggrandizement by the new Dutch state. Capitalism, one of the defining institutions of the modern world, witnessed its emergence from the feudal and mercantile world of Italian city states and kingdoms on the continent, and due to the men leading the oceanic trade consortiums, developed into the first joint-stock companies of the English and Dutch. Private capital, albeit with varying degrees of government sanction and favoritism, was diversifying the breadth of society involved in the maritime project. We also can observe this same social diversification to varying degrees in each of the Atlantic states involved in robust maritime activities. In England, capitalizing on larger segments of the population began with Henry VIII's inclusion of the gentry in the administration of his government, the attendance of their sons at universities with intentions other than the Church, and lastly, in the emergence in stature of an incipient professional maritime-trading class during the reigns of his successors. The wealth generated by their activities would further propel and expand this trend.

CHAPTER 6.
Elizabeth I, Oceans, and the Rise of State Secrecy: The Interconnected Development of Modern Institutions at Sea and at the Seat of Power in Sixteenth Century England

The Iberian project of oceanic exploration, trade and colonization, spawned a great deal of envy in the small kingdoms bounding the northwest Atlantic. They would soon struggle for global hegemony and usher in what we continue to think of as modernity. It is the purpose of this chapter to examine the concomitant development of institutions of state secrecy that emerged during the same period. It is noteworthy that these institutions were not simply focused upon diplomatic, political, and military concerns, but rather upon the cutting edge science and technology of each nation's oceanic program. This was especially the case in Elizabeth I's Tudor England.

This does not mean that even in the 'proto-navalist' circles within the Tudor hierarchy there was unanimity of views regarding how maritime technology and capabilities should be best exploited. Generally speaking, two dominant views emerged, with a third group seeing strength in aspects of both. To simplify, one camp took a long view centered on creating commodity colonies, while others argued for reaping the windfall of unrestricted piracy.[1] The elder Hakluyt, Hakluyt the Younger, and John Dee become the leading Tudor proponents of the long view for building up English prosperity through maritime expansion. They regarded the petty piracy of Elizabeth's 'Sea Dogs' like Sir Francis Drake ineffectual and morally questionable, rather, according to Taylor, they argued "not for the despoiling or dispossession of the Spaniards and

[1] Rodger, *Safeguard*, 195, notes that these policy disputes predated Elizabeth and her half-sister Mary. During Edward's short reign, "Northumberland's aggressively Protestant regime involved itself in piracy, much of it against Spain and the Empire, and trading expeditions which breached the monopolies claimed by Spain and Portugal. Already there was a distinct identification between committed Protestantism, piracy, naval service, and experimental trade into distant waters. These activities involved different groups of people, but there was considerable overlap between them, and some people were involved in all four."

Portuguese, but for the emulation of their successful overseas Empire-building."[2] Men like Sir Walter Raleigh saw profit potential in both approaches.

As Elizabeth's long reign progressed each camp was alternatively ascendant and it can be said that proponents of both setting the groundwork for empire and for ravaging Iberian maritime interests to some degree prospered. However, to achieve success in either establishing overseas colonies or waging piratical war, the principals required intelligence about the Iberians and their maritime programs, about evolving European geographic awareness, and about emerging mathematical and scientific disciplines. Stealing these secrets and protecting one's own provided the impetus for evolving state institutions centered on intelligence, censorship, and counter-espionage.

The rise of state secrecy apparatuses in Tudor England were directly influenced by, and interwoven with, the national oceanic projects of the day. These new relationships among theoretical knowledge, applied science, technology, and state secrecy developed along with the Age of Exploration. Like the oceanic project itself, government attempts to control one aspect of the nautical canon, cosmographic knowledge enabling sustained oceanic trade and control, first emerged in Iberia. However, it was in England that the connection between the rise of state security apparatuses and the emergence of naval primacy was most intense. Lacking the bureaucracies and standing armies of the larger Catholic kingdoms, the isolated Protestant nation chose to rely upon intrigue, piracy, and mimicry to preserve its independence.

In order to understand how Elizabeth's England developed state security apparatuses and an oceanic program, and the connections between the two, it is critical to examine the focus of both programs, which in many circumstances were identical. The knowledge first developed and applied in Iberia was a critical focus of England's new institutions, intelligence networks, and

[2] Taylor, *Late Tudor and Early Stuart Geography,* 2.

secrecy apparatuses. This knowledge also enabled England (along with the Dutch and French) to challenge Hapsburg Spain at sea and across the globe. This chapter examines how England purloined this intellectual and practical knowledge, but more importantly, it compares and contrasts the ways that these states chose to treat these new ‘scientific’ or ‘industrial’ secrets. The Iberian comparison is critical in evaluating the decisions made by policy makers in Tudor England.

We have examined the Portuguese nautical research project, the opening of the Atlantic and Indian trade routes, and the new science and jealously guarded secrets that were its result. We have addressed the Spanish rise to overseas dominance and its attempt to secure cosmographic secrecy under Charles V and Philip II. With this foundation, we will turn to the Tudors. England’s oceanic aspirations flourished briefly under Henry VII and produced the northern voyages of John Cabot and the discovery of the great cod fisheries off the Newfoundland banks in 1497, but waned considerably in the early sixteenth century as Spain and Portugal respectively built global colonial and trading empires. However, this was not an insignificant period in England’s maritime history. As we have discussed, the early Tudor research programs and institution building conducted during the reigns of Henry VIII and his two immediate successors, Edward VI and Mary, provided the foundation for England’s global trade and naval ambitions.

Figure 6.1. Henry VIII's *Mary Rose.*[3] This image is from one of three scrolls comprising the Anthony Roll of 1546 which captured the 46 ships of the Tudor Navy Royal. From the Pepys Library in Cambridge. Henry laid the foundation for the Royal Navy of large purpose-built sailing carracks utilizing ship-board cannon as their primary offensive weaponry, which was expanded by his Tudor successors. He established institutions like the Navy Board, developed an ordnance industry, and greatly increased England's number of capital ships. One of his largest ships (700 tons) depicted above was an unfortunate exception to his largely successful program. She capsized during the battle of the Solent in 1545, after serving for 33 years in wars against France, Scotland, and Britany. She was one of the first large warships to utilize the newly invented gun-port for her ordnance, mounted on simplified gun carriages.

With the ascension of Elizabeth I the English aggressively accelerated the oceanic contest with their southern neighbors. They did this at a perilous time in her history, a period in which domestic sectarian rifts and threats of foreign invasion where continuous and ominous. Elizabeth, adverse to both debt and anything but extraordinary taxation, expected the leaders of her Privy Council to cope with these threats without the aid of large standing armies, navies, or government bureaucracies. These men would have to both defend England on the cheap and catapult her ambitious and unruly merchant class onto the world's oceans without the benefit of a

[3] Anthony Roll as reproduced in The Anthony Roll of Henry VIII's Navy: Pepys Library 2991 and British Library Additional MS 22047 with Related Documents ISBN 0-7546-0094-7, p. 42, Photo by Gerry Bye, Original by Anthony Anthony, https://commons.wikimedia.org/wiki/File:AnthonyRoll-2_Mary_Rose.jpg.

cutting edge seafaring tradition or an advanced intellectual community versed in the mathematical, astronomical, or cartographic sciences of the day. A primary solution the leaders of the Privy Council chose, to resolve both these dilemmas, concerned the aggressive creation of state espionage and security apparatuses and the judicious use of piracy.

In order to examine this peculiar blend of method to advance the interests of the state, we will focus on four particular servants of the ruler Susan Ronald has dubbed the 'Pirate Queen' and whom Pope Pius V labelled 'servant of crime.'[4] We will look at a spymaster, a pirate, a mathematician, and a cosmographer. Each of them in their fashion understood or personified the links between sixteenth century power, oceanic prowess, and state secrecy. Sir Francis Walsingham has often been referred to as the creator of the first modern state espionage institution, but he was also an active patron of oceanic exploration, technological acquisition, and English colonialism. Sir Francis Drake was a pirate, an intrepid explorer, an accomplished navigator, a scientific patron, and Vice Admiral against the Armada. William Gilbert was a brilliant mathematician, a natural philosopher whose work on magnetism was revolutionary and deeply influential on European scientific luminaries such as Galileo and Kepler, and he was woven into the seat of Tudor power serving as Elizabeth's personal physician. Lastly, the enigmatic Dr. John Dee, who among many other things, was a cosmographer, an astrologer, a mystic, and a spy. It is the first and last of these characteristics, and the interplay between the two which we will address. It is also the connections between these four archetypes, and between England and her Iberian foes, and between the national oceanic projects and the rise of

[4] Pope Pius V issued the papal bull *Regnans in Excelsis* [reigning from on high] on April 27, 1570. In excommunicating her and her supporters, he labeled "Elizabeth, the pretended Queen of England and the servant of crime," http://tudorhistory.org/primary/papalbull.html , para 1.

state security apparatuses targeting theoretical knowledge, applied science, and oceanic technology, which this chapter hopes to illuminate.

Power Politics in 16th Century Western Europe and Transnational Knowledge Flows

This chapter posits that there were extensive connections between the Elizabethan oceanic project (to include navigation, cartography, cosmology, ordinance production, ship design, mathematics, astronomical science, instrument making, and exploration) and the rise of state secrecy in sixteenth century England. Existential international competition, state secrecy, scientific research, and hoarded scientific and technological qualitative advantages are thoroughly intertwined today. This admixture of technological advantage and dramatic efforts to develop, purloin, or protect scientific or technological insight, and the commensurate impact on interstate power relationships can be traced back to at least the early modern period in Western Europe. Although many of the national secrecy directives, intelligence networks, and security apparatuses – broadly defined herein as embryonic state security institutions – that arose during the early modern period were inspired by sectarian divisions in what had heretofore been a monolithic Western Christendom, a less noted inspiration for their development can be perceived in the early modern project of sustained oceanic exploration, trade, and colonization. This was definitely the case in Tudor and Stuart England. The concomitant rise of Elizabethan state security institutions and the expansion of the English overseas project were connected, directed in large part by the same actors, and mutually dependent.

The cutting edge power and wealth producing technology of the early modern period was nautical. During this period hitherto uncrossable obstacles representing the ends of the known world were irrevocably transformed through scientific exploration, which started with the

Portuguese African foray in the fifteenth century.[5] Oceans were transformed into trade highways, avenues of colonial expansion, and competitive national battlefields. The science and technology that fueled this expansion was both a product and a driver of the emerging Scientific Revolution.[6] The qualitative advantage provided by better astronomical ephemerides, more precise solar observation instruments, expanding geographical knowledge, new hydrographic knowledge, improved cartographic technique, cost effective ordnance production, or better ship design could give one nation a vast advantage in growing an empire, in strangling the trade of an adversary, in expanding national wealth, or in protecting the nation's survival. Cognizant of these facts, national elites of the period actively sought to safeguard their own burgeoning cosmographical canon, wrest any technical nautical advantage from their neighbors, refine their astronomical navigation science, and secure naval dominance for their own state.

This maritime competition was conducted in a region at war both abroad and within its own fragmented borders. The dominant European power of the mid-sixteenth century was Spain under the Hapsburg rule of Philip II. Although locked in a military stalemate in the Mediterranean with the Ottoman Empire, Philip controlled the world's largest global empire.

[5] A great deal of early nautical technology was empirically driven; however, as we have seen the Portuguese oceanic program had scientific roots. This fact contradicts the general consensus today among modern historians of technology that technological developments had primarily empirical roots throughout much of history. Joel Mokyr, *The Lever of Riches*, 113, in his examination on technological development up to the dawn of the twentieth century, contends that, "it is widely believed that before the middle of the nineteenth century, technological progress moved more or less independently of scientific progress, and that since then the interaction between science and technology has gradually become tighter." Mokyr conditions his assertion with the following observation: "As we have seen, this is only partially correct. Science, and especially scientists, were [sic] not totally irrelevant to technological change before 1850." The year 1850 serves as a watershed year for historians of technology – the birth of science based industries distinctly altered their perception of technological origin. Mokyr explains that, "after 1850, science became more important as the handmaiden of technology. A growing number of technologies, from waterpower to chemicals, depended on or were inspired by scientific advances." As Taylor, Law, Portuondo, Sandman and others have shown, Western oceanic exploration and its derivative technologies was inextricably wedded to the early modern sciences of astronomy and cosmography and appears to be one of Mokyr's rare exceptions to early technology's empirical roots.

[6] This link between the emergence of modern science and oceanic exploration was proposed at least as far back as Francis Bacon's day. Jack Beechum, 12, notes in his introduction to Hakluyt's *Voyages and Discoveries*, Bacon's observation in the *Advancement of Learning*, "This proficience [sic] in navigation and discoveries may plant also an expectation of the further proficience [sic] and augmentation of all sciences."

His American possessions and Eastern trade funded armies and navies that fought from the Balkans to Northern Europe. With the other great continental land power, France, convoluted with civil strife, the Protestant rulers of Holland and England faced an unrestrained existential threat from the Catholic monarch. Unable to contest Spain on land, Elizabeth's island nation turned seaward.[7] They did so at a time when Spain's oceanic enterprise was almost a century old and had settled into bureaucratic consolidation. Late sixteenth century Hapsburg Spain was living off the fruits of Iberian fifteenth and early sixteenth century conquests. Their focus was not primarily on expanding their colonial empire, but on maximizing its wealth production to advance their objective of consolidating a universal Catholic Europe. Northern Europeans entered the colonial race late, but they were aided in their ambitions by adopting Iberian technology and by poaching on the claims of an extended and distracted Spain. As Fernand Braudel remarked in his epic history of Philip II's Mediterranean world, "While France and Spain were fighting over townships, forts and hillocks of ground, the Dutch and English were conquering the World."[8] They did this at sea.

Tudor England was late to join the Iberian powers exploring the Atlantic and Indian Oceans. It entered the Atlantic race as a fishing power on the Newfoundland Banks. But it would quickly expand its naval acumen, actively contest Spain in a piratical war of attrition, defeat its erstwhile Dutch ally in the seventeenth century and emerge as the world's preeminent naval power. The science and technology England acquired towards this end had many sources and would require new forms of production and protection. Strange pairings of sailors and spymasters, pirates and explorers, scientists and astrologers, would assemble this knowledge. They would institutionalize both their navy and science, creating modern organizational

[7] Glete, 147, notes that "together with the England, the Dutch developed superior maritime technology and organization for war with which they were able to challenge the Iberian powers."
[8] Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II,* 1220.

structures and intellectual paradigms which are still dominant throughout the West, and in turn exploit and amplify the effectiveness of their nautical canon.[9] This modernization was often led by the classically (and legally) educated rising gentry and characterized by the creation of permanent administrative state and private organs to replace informal feudal counselors and to supplement the output of medieval universities. But it was also promoted by merchants, sailors, ship's masters and navigators, and self-taught mathematicians, all of common birth, and before their mutual ascendance, all from groups considered low by the rulers and propertied interests that ran Europe's feudal states.

When Elizabeth ascended to the throne in 1558, England was torn by the sectarian rule of Mary and her Spanish consort, King Phillip II. England had lost its primary staple export market in Calais as a consequence of supporting Phillip in his war against France, and despite some Spanish oceanic tutelage, they were still forbidden to encroach upon the monopoly trade routes administered by the Casa. The English faced a decision point: compete with the Iberians on the global stage by creating a robust maritime establishment, or remain a poor and besieged heretic enclave. Elizabeth and the nation chose the sea and as Waters observes,

> "… guided by the unobtrusive genius of Sir William Cecil [Lord Burghley], the English were at last taking whole-hearted measures to maintain and increase their navy, navigation, and seamen. The necessary supplies of timber and naval stores were being

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[9] Even though Henry VIII inherited a small navy from his father Henry Tudor (VII), he has been regularly credited with creating the modern institutions of his Navy Royal (this term was superseded by the 'Royal Navy' in 1660 – Konstam, *Sovereigns*, 12).

Robson, John, *Captain Cook's War & Peace: The Royal Navy Years 1755-1768*, 144, notes with the 1660 restoration of Charles II, the navy officially became the Royal Navy. "In 1661 Sir William Penn and Samuel Pepys established the Naval Discipline Act, which included the articles of war and founded the Royal Navy by Statute."

Officially titled: *An Act for the Establishing Articles and Orders for the regulateing and better Government of His Majesties Navies Ships of Warr & Forces by Sea*.

Herman, *To Rule the Waves*, 35-36, 42, notes that early in Henry VIII's reign, before his reforms, the Lord Admiral was a judicial post and that this office holder was a boy of seven. Henry created the Navy Board in 1545, and he was the visionary responsible for converting the small navy of boarding and melee craft he inherited into a formidable sailing force of bronze gun platforms.

Rodger, *Safeguard*, 223, notes that although the Lord Admiral was in fact a child from 1525 (the king's illegitimate son the Duke of Richmond), Cardinal Wolsey used the vacancy to direct the navy through its Keeper of the Storehouses, William Gonson.

safeguarded, and the shipyards and shipwrights for ship-building encouraged; a sufficiency of seamen and masters to man the ships, and of pilots to conduct them in and out of port and overseas, was being assured; better sea-marks, surer land-marks, safer ports for lading and discharging cargoes – all were being legislated for, and, as we shall see, the legislation was being made effective through the medium of Trinity House."[10]

This was not policy merely forced down from the Privy Council, but one embraced by the nation's nobility, its merchants, its scholars, and its people as evidenced by a generation of laws from parliament giving primacy to nautical interests, national maritime power, and mercantile strength.[11] England required more than updated ships and sailors for its quest, but hardy institutions that could amalgamate a nautical canon and disseminate it to a large, diverse, and unruly maritime community. By changing the nature of the institutions involved in maritime affairs and focusing their efforts on a unified national goal, England was able to go from nautical laggard to a rising global leader in maritime affairs in less than a generation.

The inspiration for many of these institutions or their adaptation, like much else concerning the Tudor nautical program from navigation to ship building, came in part from Spain and from practical considerations. In 1514 Henry VIII granted a Royal Charter to The Master Wardens and Assistants of the Guild Fraternity or Brotherhood of the Most Glorious and Undivided Trinity and of Saint Clement in the Parish of Deptford Strond [sic] in the County of Kent, simply known as Trinity House (Deptford Strand), for advancing navigation and licensing English pilots.[12] He issued his charter officially incorporating the body and granting it

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[10] Waters, 103, emphasizes Cecil's critical role in structuring the Elizabethan mercantile endeavor, 101, "It is impossible to dissociate the name of Sir William Cecil, later Lord Burghley, from the history of English maritime achievements. It is not too much to say that he was the presiding and directing genius behind them from the first day of Elizabeth's reign until his death in its closing years."

[11] Ibid, 100-103.

[12] Buckton, T.J., *Notes and Queries,* **3rd S. VI. 149.**, September 3, 1964, 191, these houses trace their non-chartered past to mariner's guilds from the Middle Ages were set up on monastic principles to care for "decayed pilots and seamen, their wives and widows."

Robson, 40, observes that Trinity House may have traced its roots to the thirteenth century Guild of the Holy Trinity.

jurisdiction in response to a petition by a guild of mariners whose concerns about inexperienced pilots and the disclosure of the Thames's secrets to the enemy were painfully evident during Henry's 1513 campaign against France. They wanted the authority to regulate pilotage on the Thames,

> "The practise of pilotship in rivers, by young men who are unwilling to take the labour and adventure of learning the shipman's craft on the high seas, is likely to cause scarcity of mariners; 'and so this your realm which heretofore hath flourished with a navy to all other lands dreadful' shall be left destitute of cunning masters and mariners; also that Scots, Flemings and Frenchmen have been suffered to learn as loadsmen [pilots] the secrets of the King's streams, and in time of war have come as far as Gravesende 'and sette owte English shippes to the great rebuke of the realm.'"[13]

Henry granted a charter to the guild and to two others centered in the London entrepôt. These new houses had limited jurisdiction and tolling authority during Henry's reign, but their influence would grow with Tudor maritime ambition. And a man of common origin and practical experience rather than university and social pedigrees was again critical.

Trinity House (Deptford Strand) and its sister houses were not initially focused upon incorporating the new astronomical navigation or assembling cosmographical data as in Spain, but rather upon safeguarding English shipping on its rivers, coasts, and its regular limited trade routes.[14] Elizabethan legislation expanded the scope of the Trinity Houses and instituted its principal role in increasing English maritime proficiency. As Waters notes, "The man behind the initiation of this important legislation and the increased activities of the Trinity Houses was Stephen Borough."[15] Borough did not just return from the *Casa de Contratación* with Cortez's navigation manual. He had grander designs to emulate Spain's maritime infrastructure.

Waters, 9-10, 109-110, and https://www.trinityhouse.co.uk/about-us/history-of-trinity-house. Similar Trinity houses followed in Kingston upon Hull (1541) and Newcastle upon Tyne (1536). All were chartered by Henry VIII and centered on London.

[13] https://trinityhousehistory.wordpress.com/tag/henry-viii/.

[14] Trinity House (Deptford Strand) was specifically charged with safe-guarding shipping on the River Thames and was chartered on May 20, 1514 by the crown.

[15] Waters, 103.

Although he neither achieved his goal of establishing a single Chief Pilot or a single bureaucracy like the Spanish Casa in England, men like Cecil were able to harness his appreciation for the depth of the Spanish maritime canon and adapt existing English institutions towards achieving the same purpose of enhancing maritime proficiency, without succumbing to the ossification that plagued the Spanish maritime bureaucracy in the mid-sixteenth century.[16] The Trinity Houses would become not just clearing houses for navigational knowledge, licensing authorities, and lighthouse keepers, but active participants in generating cutting edge nautical and natural science as Edward Wright's dedication remarks concerning Trinity House in his 1599 translation of the Dutchman Simon Stevin's *The Haven-Finding* Art attests.

Figure 6.2. Cornerstones of English navigation. Richard Hakluyt's ***Voyages and Discoveries****: The Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation …*, first printed in 1582; title page 1589

[16] Sandman and Ash, 804, and see Waters, 106.

edition (left).[17] This chronicle of English exploration and colonization is much more than just polemic and nationalist propaganda. It is one of England's first great geographies and was compiled by the author from myriad interviews with a large number of the participants. The 500th Anniversary Commemoration of Henry VIII's issuance of a Royal Charter to Trinity House (Deptford Strand) (right), an organization that did so much to improve English seamanship and safe-guard them on its shores.[18]

Contemporaneous with the development of these institutions, England created national institutions to safeguard state secrets and to steal those of its competitors. Short of outright military movements in wartime, the most important secrets a sixteenth century state could protect or steal were nautical. This could include new navigation science, ship design, knowledge of prevailing winds, geographical discoveries, and as the mariner's petition above exemplifies simple hydrographic data such as channel depths. Although Secretary of State Sir Francis Walsingham and Lord Treasurer Burghley's intelligence networks were undoubtedly a direct byproduct of the sectarian strife of the period, Elizabeth's England (and that of her Stuart successors), they also granted primacy to nautical secrets. In addition, they pioneered the modern state intelligence apparatus at the same time England was institutionalizing the research establishment of modern science. Both developments were intertwined and both often involved the same actors. Kristie Macrakis, in her *Intelligence and National Security* paper "Confessing Secrets: Secret Communication and the Origin of Modern Science," notes the historical irony from the early modern period, "that those who espoused openness in science, reconciled that ethos with secrecy in affairs of state." [19] Focusing upon the seventeenth century pillars of the early Royal Society like John Wilkins, John Wallis, and Robert Boyle, she notes their role in state secrecy, and at times espionage work. Science and espionage, nautical and sectarian secrets, all percolated together in the same milieu.

[17] "Richard Hakluyt," Wikipedia.org, https://en.wikipedia.org/wiki/Richard_Hakluyt#/media/File:RichardHakluyt-PrincipallNavigations-1589.jpg.
[18] Trinityhousehistory.wordpress.com, https://trinityhousehistory.wordpress.com/tag/deptford/.
[19] Macrakis, "Confessing Secrets: Secret Communication and the Origin of Modern Science," 183.

It is critical at this point to define the term state secrecy. Political leaders have been keeping secrets, obscuring military buildups and maneuvers, and instructing diplomats to both spy and lie throughout recorded history. However, our concern lies with both the building of state institutions, intelligence networks, operational paradigms, and with the nature of the information that served as their object. In order to safeguard national secrets and purloin those of others, modern states develop institutions and participate in a number of activities including: restricting access to secrets only to trusted nationals, by export restrictions, through censorship, through state control of critical industries or intellectual disciplines, and through both domestic counter-espionage and foreign espionage. This chapter continues many earlier arguments that identify the first embryonic state security apparatuses with those of late Tudor and Stuart England.[20] Although often run and personally financed by individual Privy Councilors like Burghley, Walsingham, and the Earl of Leicester, these intelligence networks were used in the Protestant monarch's long undeclared war against Philip's Catholic empire and his French, Irish, Scottish, and English coreligionists. In addition to establishing intricate intelligence gathering networks, they setup nascent bureaucracies for encoding and decryption, for secure and quick message delivery, for propaganda distribution, and for domestic censorship of privileged information. Privy Councilors like Walsingham and private men of stature like Dr. John Dee collected enormous amounts of intelligence information. In many cases, this information was of a nautical character. They focused their efforts not just upon monitoring fleet buildups and shore defenses, but upon the entire project of oceanic exploration and colonization. Although some of

[20] Haynes, *The Elizabethan Secret Services*, 29, notes "If secret services existed only in skeleton form in 1572, five years later the work being done was beginning to show a modest efficiency, a sound basis for growth in effort in the tumultuous 1580s, when Walsingham's employment of spies became systematized." Walsingham built up an extensive network of "intelligencers", tradesmen, diplomats, code clerks, prison spies, torturers, and post horses to keep track of Catholic intrigue at home and throughout Europe as far as Ottoman Constantinople.

Macrakis, 191, notes that "In fact, the origins of a notion of national security seem to have begun in seventeenth century England."

the intelligence information assembled by these networks was not subject to foreign state censure, a great deal of it relating to the maritime project was explicitly regarded as the private property of the state.

Modern institutions as varied as institutionalized national navies, scientific societies, and state espionage services had their roots in the same milieu that produced the explorers, pirates, astronomers, and mathematicians of the period. The object of one group often was the propellant of the other. Critical actors moved between and connected all these groups. The connections between these embryonic institutions during the early modern period and the relationship between science and the state that emerged from Western Europe's assault on the seas are embedded in our current institutions and for that reason alone, are worth study.

Although preceding the Scientific Revolution and its purported embrace of open dispassionate examination, the early Age of Exploration was not launched from the dark recesses of European history. Whether one chooses to believe that the Scientific Revolution was an historical watershed event, that it was initiated in the early seventeenth century, or that it was even an epistemological gestalt change worthy of note, the modern scientific ethos of making knowledge public to enable contemporaries to attempt falsification through experimentation (or in contrast, to attempt Kuhnian paradigm confirmation) could lead one to the false impression that all knowledge was closely guarded and heavily censured in early modern Europe. In fact, the guild secrecy that existed at the time for technical processes and the esoteric nature of the early sciences was counterbalanced by the open scholastic attempt to rediscover the scientific truths known to classical civilization.[21] More to our point, the early sixteenth century European

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[21] Hull, David, "Openness and Secrecy in Science: Their Origins and Limitations," *Science, Technology and Human Values,* 4-5.

state was not actively involved in the suppression of knowledge dissemination across national borders.

The scholastic and Aristotelian worldviews prevalent among early modern Europe's scholars and proto-scientists acknowledged the classical dictate that although practical skills belonged to the marketplace (*technē*), natural knowledge (*epistēmē*) was only justified in public.[22] Although encryption was used regularly by scholars and experimentalists of the period, they used it to secure authorial primacy for their theories or to safeguard potential commercial applications. Alchemists and healers guarded their personal secrets, but even these were useless to them unless put into some type of public practice. Joel Mokyr notes in his classic work, *The Lever of Riches* that technological innovation requires a social diversity and tolerance and the free flow of ideas that indeed existed in Medieval Europe.[23] The relatively weak states of the day had little involvement in controlling astronomical, mathematical, or natural knowledge.

However, the advent of the Columbian landfall and the resultant wealth that poured into Europe over the ensuing decades, helped to alter the benign perception of the state towards scholarship and its relation to scientific and practical knowledge. By the seventeenth century, even Francis Bacon, the father of the empirical method and the inspiration behind the Royal Society noted the proper role of government secrecy regarding some scientific discoveries,

> "Concerning government, it is a part of knowledge secret and retired in both these respects in which things are deemed secret; for sometimes things are secret because they are hard to know, and some because they are not fit to utter."[24]

Bacon was deeply impressed by the power emerging technologies could have in shaping world events as his comment on the three critical discoveries of modernity illustrate,

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[22] McMullin, Ernan, "Openness and Secrecy in Science: Some Notes on Early History," *Science, Technology and Human Values*, 14-15. Also see Long, Pamela O., *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*.
[23] Mokyr, Joel, 12 and chapter 3.
[24] Bacon, Francis, *The Advancement of Learning* (1605), Book II, paragraph 47, 248.

> "… printing, gunpowder, and the compass. For these three have changed the appearance and state of the whole world: first in literature, then in warfare, and lastly in navigation; and innumerable changes have thence derived, so no empire, sect, or star, appears to have exercised a greater power and influence on human affairs than these three discoveries."[25]

It is easy to brandish this as simple technological determinism, but the larger point Bacon is making is that the connection between scientific and technological discoveries and national advantage is unambiguous. However, this connection between science and state power and the proper way to control knowledge posed novel problems to policy makers and the learned in the sixteenth century as the Atlantic kingdoms first discovered and then responded to the unavoidable relationship and connections between the new nautical sciences and state secrecy.

Geographic data, astronomical navigation techniques, and cosmology all became subjects of both secrecy and espionage. Institutions originally designed to protect the monarchy from direct personal threats were also used to both hide and steal nautical information. The Age of Exploration coincided with organized efforts to hide science; nations no longer just hid military or diplomatic secrets. And like the Age of Exploration itself, some of these efforts have distinct Iberian roots. When in the fifteenth century, the Avis monarchs wedded science to oceanic exploration, they immediately realized they had wealth producing knowledge that was best not shared. The rulers of Tudor England faced the inverse of this dilemma. They noted the success of their Iberian rivals, and of their French and Dutch imitators, and needed ways to obtain this knowledge quickly and on the cheap.[26] To Elizabeth's Privy Council, this problem was an existential one. The island nation, isolated from Catholic Europe and susceptible to beachheads in Scotland, Ireland, and Wales, was vulnerable without a modern navy, and now that its cross-channel European wool trade was stymied, slated for impoverishment without the reach of a

[25] Bacon, Francis, *Novum Organum*, Book I, CXXIX, 105.
[26] Glete, 149, notes that "up to the 1560s the threat against Spanish Atlantic trade and American settlements came from France" and that, 152, "the Huguenots were especially strong on the Atlantic coast. Much of the seafaring population turned Protestant and the great port of La Rochelle became [their] most important stronghold."

global merchant marine. The erstwhile student of maritime Spain would opt for intrigue and piracy to resolve this threat.

Walsingham's Espionage Apparatus

One of Elizabeth's closest Privy Councilors, her Secretary of State, Sir Francis Walsingham, would be actively involved in a wide variety of clandestine and official activities targeted at emulating Spanish nautical expertise and in protecting the budding cosmographic and navigational knowledge being generated by England's new 'Merchant Adventurers.' A number of scholars have noted the similarities between the educated rising gentry that both Philip II and Elizabeth I preferred to use to administer their governments. [27] In 1569 Philip II ordered an audit of the Council of the Indies. The four year exercise was led by the man of letters (*Letrado)* Juan de Ovando y Godoy. Ovando reached a conclusion that Spanish mismanagement was the result of a lack of information in the Council, but was also due to a lack of clearly codified laws. Trained in the law as well, Walsingham, and his mentor William Cecil (Lord Burghley), also believed that good governance and their sovereign's survival could only be secured if the Privy Council had extensive and accurate information.[28] The information they sought was not just confined to rebellions, plots, and Catholic sedition. Walsingham and Cecil, as well as the third

[27] Portuondo, 115, "Ovando is a prime example of the kind of man Philip II sought for the administration of his expanding empire. *Letrados* or men of letters like Ovando held many important positions that had formerly been awarded only to gentlemen of high birth." Pg. 116, Portuondo presents an interesting comparison between Ovando and Bacon – both started with a legal reform (Bacon circa 1614) that led to subsequent reforms of science. Pgs. 138-139, Referencing Barbara Shapiro and Julian Martin, "the epistemological philosophy of Francis Bacon, with its emphasis on witnessing and firsthand accounts as a means of ascertaining 'matters of fact,' was profoundly influenced by his legal training. This was also the case nearly forty years earlier with Juan de Ovando and the *Instructions*. … Bacon would go that one crucial step further and define the epistemic and methodological how-to of fact construction. He addressed the question Ovando left – save for a few cases – unanswered: how 'things' were to be 'known' and how they were to be 'investigated.'"

[28] Budiansky, *Her Majesty's Spymaster: Elizabeth I, Sir Francis Walsingham, and the Birth of Modern Espionage*, 33-37, notes that Walsingham was educated at Cambridge and abroad, "when he could afford it, became a patron of the arts and sciences, supporting voyages of discovery, [including] the search for the Northwest Passage… He was curious about the science of navigation. Robert Hakluyt dedicated the first edition of his collective tales of discovery to Walsingham." Thoroughly Puritan, Walsingham was also a Renaissance man. He was "a zealot who knew how to keep his mouth shut."

member of Elizabeth's ruling triumvirate, Robert Dudley, the Earl of Leicester, not only sponsored oceanic projects, but used their intelligence networks to gather nautical information of all kinds.   The chief early modern propagandist for British Empire and chronicler of England's seafaring tradition, the younger Richard Hakluyt, not only dedicated the first edition of his *Navigations, Voyages, Traffiques and Discoveries of the English Nation,* to Walsingham, but he served as a diplomat and spy for him in France, where he was tasked with discovering foreign cosmographic information in addition to details on fleet construction and deportment.

Walsingham also proposed a number of naval missions to the Queen for the purposes of exploration, to enhance England's strategic position against the Spanish, to retaliate against Spain's interference in trade, and often for purely commercial reasons that would both limit Spanish resources available for assembling aggressive expeditions against England and serve personal investment purposes. When in 1585, as the tension with Spain was accelerating from incident laden armed truce to open war, Walsingham recommended,

> "A plot or device, in Walsyngham's [sic] hand, for annoying the King of Spain by the seizure of the Spanish shipping at Newfoundland; the benefits that would follow by distressing the navy of Spain, and the advantages to England. Such a measure would be likely to be taken by the King of Spain as an open act of hostility."[29]

Elizabeth did dispatch a force to both protect English shipping and commandeer the Spanish vessels in the area as is recounted in the following order,

> "Commission to Bernard Drake, Esq., to proceed to Newfoundland to warn the English engaged in the fisheries there, of the seizure of English ships in Spain, and to seize all ships in Newfoundland belonging to the King of Spain or any of his subjects, and to bring them into some of the western ports of England, without dispersing any part of their lading until further orders."[30]

[29] SP12/176/2 f.153, "A plot or device, in Walsyngham's hand, for annoying the King of Spain by the seizure of the Spanish shipping at Newfoundland; the benefits that would follow by distressing the navy of Spain, and the advantages to England," March ? 1585.
[30] SP 12/179 f.47, "Commission to Bernard Drake, Esq.," June 20, 1585.

Walsingham also acted as a clearing house for petitions from various men of means who wanted to get their naval projects approved as this letter from Sir George Carey illustrates,

> "Sir George Carey to Walsyngham. Desires to know how Her Majesty intends to revenge the arrest of the English shipping and goods in Spain. Offers to fit out privateers at his own charges to make reprisal on the Spaniards. Offers of one Flud, a valiant and skilful pirate, to survey the coasts of Spain, and bring intelligence what preparations were making."[31]

There were in fact quite a number of "Plots to Annoy the King of Spain," submitted by Walsingham to his sovereign and they quite often involved the private naval services of men like Sir Francis Drake, whom Walsingham had sponsored on his three year circumnavigation and Peruvian coastal raids of 1577 to 1580.[32] It is instructive to look at the career of Drake, one of Elizabeth's most successful 'Sea Dogs,' in order to discern the interwoven threads of Privy Council politics, the emerging state security networks, English cosmography, and its emerging nautical tradition.

Sir Francis Drake – Elizabethan Exemplar

Drake, like many of England's legendary mariners had roots and family connections in England's West Country.[33] As a young man, the deeply Protestant Drake gained experience sailing for the Hawkins shipping family and had earned a ship command under John Hawkins on his armed trading expedition to the Spanish Main in 1568. Although the expedition ended in the disastrously bloody battle of San Juan de Ulúa, the encounter proved pivotal in the slowly escalating war for trading rights on the Atlantic.

[31] SP 12/179 f.80, "Sir George Carey to Walsyngham," June 25, 1585.
[32] Budiansky, 180
[33] Herman, 25-30, recounts the West Country seafaring tradition associated with the counties of Cornwall, Devon, Somerset, and Dorset, an area he dubs "the original nursery of England's overseas empire and the British navy."

For years the Hawkins brothers had 'forced' trade with the underserved Spanish colonies in the Caribbean, bringing in European trade goods and African slaves. Hakluyt traces the ambitions of the brothers (William the younger and John) to the senior William Hawkins, who

> "… not contented with the short voyages commonly then made only to the known coasts of Europe, armed out a tall and goodly ship of his own of the burthen of 250 tuns, called the *Paul of Plymouth,* wherewith he made three long and famous voyages unto the coast of Brazil." [34]

These voyages, conducted from 1530 to 1532 predated Cabot's return to England and established the Hawkins family as one of the leaders of the West Country Merchant Adventurers. However, failing to open Spanish markets, English merchants discarded any pretense of peaceful trade, and turned whole heartedly to piracy, albeit under the legal cloak of English Letters of Marque.[35] In the following years Drake led some of the most successful raids against Spain's Caribbean possessions by forming an allegiance with the *cimarrrones* and ambushing silver shipments crossing the Isthmus of Panama.[36] His activities were harmful enough to Spain's interests to attract the attention of the Spanish court, as the Spanish complaint, tendered to Queen Elizabeth, and demanding punishment for Drake and recompense for Spain, attests,

> "A Relation of the information's given to his Majesty's Council of the Indies of the many injuries and robberies committed by English pirates in the ports and on the coasts of the Indies upon the vessels and goods of his Majesty, especially in the year 68.
>
> In the port of Cartagena, an English man, a resident of Plymouth, named Francis Drake, pilot, who was with John Haquins [Hawkins] when he was at S. Juan de Lua, entered the port by night and sacked a ship of Bartolomeo Farina of 180

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34 Hakluyt, Richard, Navigations, *Voyages, Traffiques and Discoveries of the English Nation,* 51-52.

35 Rodger, 128, notes that the term Letters of Marque is somewhat anachronistic, and the more accurate label, stemming from medieval tradition, is Letters of Reprisal. Rodger traces 'royal licenses' to commit piracy to the 1290s at the latest. In theory, private parties were licensed by the crown to seize shipping from a country that had wronged a citizen in order to compensate them for their loss. The citizen must first have been denied legal recourse from the offending nation, and again in theory, his commission would be limited to his loss and expire when he recouped the set amount of that original loss. These letters of reprisal eventually evolved into the unconstrained piratical licenses better known as Letters of Marque.

36 Bawlf, 31-32, the *cimarrrones* were escaped black slaves that had intermarried with the local Indians and fought a low intensity guerrilla war against the Spanish.

> tons, and having taken everything of value, burnt the ship and took the said Farina captive to England.
>
> And the same Francis Drake entered Nombre de Dios at midnight, and killed eighteen persons, and proclaimed war on behalf of the Queen of England, and sacked in the port a vessel of Francisco Gallego, laden with wines.
>
> He also took a carvel which the officers of his said Majesty of the House of Commerce at Seville had sent with powder and lead and other munitions of war to the Havana, and ***seized one Francisco Ravano, a pilot and threw him into the sea, because he would not show them the ports.*** [emphasis added]
>
> And the same robbed the lieutenant of the governor of Cartagena of all that he had in a frigate. He also took two frigates, one being that of James Raphael, the other of Sebastian de Proença, one of which is at Plymouth and the other is said to be sent to the Indies.
>
> Moreover he has taken many other frigates, with great quantity of gold, silves and merchandize, which were going to the coast of Tierra Firme and Veragua."[37]

This account goes on for several more pages, but it is important to highlight the comment about the pilot. Drake, although a skillful astronomical navigator in his own right, was heavily dependent upon the local knowledge accumulated by the Spanish and Portuguese navigation programs. Early in his career, he realized that capturing charts, rutters, and pilots was essential if he was to sail successfully in enemy territory. This was a lesson he would never forget and a pattern he and his contemporaries repeated throughout the period.[38] Whether Drake threw Ravano overboard or not is unknown. We do know that Drake regularly captured pilots,

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[37] SP 70/146 f.94, "The Spanish King's Complaints of English Piracies," End of 1575.

[38] Taylor, 208, "Francis Drake, when he went off quietly 'for Alexandria' in the following year [1570], provided for his navigation by always kidnapping a pilot who knew the particular part of his route, and to decide his general plans he bought a large world chart in Lisbon."

Sandman, 37, "Both charts and pilots were liable to be captured by pirates or enemy warships. … Drake seems to have made a habit of capturing pilots and interrogating them about local conditions."

Repeated instances are included in Bawlf.

Hakluyt, "Voyage of Francis Drake about the whole globe," is conspicuously silent on the contributions of the captured pilot in regards to his aid in navigating through Strait of Magellan and into the Pacific Ocean, although he recounts Drake's capturing of Spanish fishing vessels near Barbary and Portuguese caravels off the coast of Guinea (172) on his outbound journey. He does mention Drake's capture of pilots along the Chilean coast and their use in entering harbors – the Greek 'John Griego' for Lima (177) and the Spanish pilot he captured in his first battle after he captured the *Cacafuego*, who brought the English into Guatulco (179). Hakluyt seems willing to credit these pilots only with providing local coastal intelligence so as not to diminish any of Drake's more remarkable blue water navigation accomplishments.

threatened them with being tossed overboard for noncompliance, but also that he regularly set them ashore unharmed, and occasionally compensated them, if they guided his craft through the extremity of their local competence.

Drake's English contemporaries also understood that Iberian pilots where a wonderful storehouse of sailing information and a repository for state secrets. The Portuguese Admiral Joao da Nova Castella first discovered the remote South Atlantic island of Saint Helena in 1502 on an outward trip to India. The location of the island mid-way through the South Atlantic Gyre made it an ideal watering, provisioning, and anchorage point for Portugal's India fleet. The Portuguese were not prepared to share this useful base and they were able to keep its location a closely held state secret for almost a century. However, Richard Deacon notes that,

> "It was not until 1588 [eight years after Philip II became King of Portugal] that Captain Thomas Cavendish became the first Englishman positively known to have reached St. Helena. He had discovered the whereabouts of this small and isolated South Atlantic island, which the Portuguese had kept secret for eighty-six years, from the pilot of a Spanish vessel he had captured."[39]

Due to the success of his Caribbean *Nombre de Dios* campaign and the healthy return that Drake earned his investors and the Queen, and because he had escaped legal censure, he proposed a much grander project. His proposal had the twin objectives of exploration (the circumnavigation of the Western hemisphere with a return route eastward along the undiscovered Northwest Passage) and a commerce raiding mission along Spain's unguarded Peruvian coast.[40] However, even the exploration half of the mission needed state approval, powerful patrons, and the disinformation resources they controlled. Samuel Bawlf notes the fortuitous revelation by

[39] Deacon, Richard, *John Dee: Scientist, Geographer, Astrologer and Secret Agent to Elizabeth I*, 52-53.

[40] Rodger, *Safeguard*, 243-244, notes that Drake's plan was inspired by "Greenville's earlier proposal, expanded to cover an armed reconnaissance into the Pacific." He also notes the pedigree of the plan's sponsors including "Sir Francis Walsingham the Secretary of State, Sir Christopher Hatton, the Earls of Leicester and Lincoln – the group of aggressive, Protestant-minded courtiers who consistently argued for overseas expansion at Spanish expense."

Bawlf, 62, Richard Grenville (later killed during the last battle of the race-built galleon *Revenge* in 1591) first proposed searching for the Northwest Passage from its southwestern opening.

Walsingham of Don Juan's plan to invade England with the French Duke of Guise in 1577. "Walsingham's reports to [of] Don John's [Juan's] plot undoubtedly were what had cleared away the Queen's hesitation concerning Drake's venture."[41] Walsingham then had John Hawkins (as Treasurer of the Navy) draft bogus reports indicating Drake was headed for Alexandria.[42] But the Spanish also had spies in England and they monitored Drake's movements regularly. What followed was a convoluted game of story and counter-story until Walsingham convinced the Spanish that Drake was headed northward to kidnap the Prince of Scotland.

Thus conceived strategically, and launched in a fog created by Elizabeth's greatest spymaster, Drake began England's most ambitious voyage of exploration. In his three-year trek, he would kidnap Portuguese pilots, force the Straits of Magellan, discover the eponymous Drake's Passage, and the strategic knowledge that the island of Tierra del Fuego was not the tip of the great Australian southern continent (thus rendering useless efforts to fortify the 'entrance' to the Pacific). He would wreak havoc on the Pacific coast of Spanish Peru, plunder enormous amounts of treasure, and sail further north along the coast than any previous European. He confirmed that North America was not nearly as broad from east to west as mapmakers at the time believed and that the hemisphere was not connected to Asia in the north. Bawlf and others believe that he reached 50 degrees north latitude and that Drake actually believed he had reached the mythic Strait of Anian, the southwest Pacific opening of the Northwest Passage. Nearing winter and fearing an iced over passage, he sailed west across the Pacific and returned to England in the *Golden Hinde*, the last of the five ships he had departed in three years earlier.[43] Drake's *Pelican* (later the *Golden Hinde*) was purposely disguised as a merchant bark. Drake

[41] Bawlf, 68.
[42] Hakluyt, 171, begins his record of Drake's 1577 voyage with, "…giving out his pretended voyage for Alexandria."
[43] Bawlf, 6.

also built it for durability, piracy, and high latitude exploration by including a double planked hull, specifying a shallow draft (13'), including a big hold for stores and four pinnaces (used for coastal raiding), ensuring it was heavily gunned for stand-off fire, and equipped with an extensive sailing rig.

Map 6.1. The world before the circumnavigation of Sir Francis Drake, 1577-1580: Abraham Ortelius' 1570 map of the world, *Typus Orbis Terrarum,* depicts a North American continent forty degrees of longitude wider than actual, a Northwest Passage into the Pacific from the North Atlantic, and a contiguous South American and Antarctic continental link at the Straits of Magellan. Drake's discoveries had dramatic sixteenth geopolitical implications, but were kept secret for years by Elizabeth's spymasters.[44]

[44]Abraham Ortelius (Abraham Ortels) (April 14, 1527 – June 28, 1598) was a Flemish cartographer and geographer; he was heavily influenced by Gerard Mercator and is generally recognized as the creator of the first modern atlas, the *Theatrum Orbis Terrarum* (Theatre of the World). In 1575 he was appointed Geographer to the King of Spain, Philip II. His 1564 map, *Typus Orbis Terrarum*, indicates the state of European global knowledge in the late sixteenth century to include the two critical errors discovered by Drake: (1) the existence of a water route around Tierra del Fuego (Drake's Passage) and the separation of the Antarctic (*Terra Australis Nondum Cognita*) and South American continents and (2) the excessive breadth of the North American continent by forty degrees of latitude, with the commensurate knowledge of a wider Pacific and a lack of a North American and Asian land bridge. A surviving 1570 reprint appeared in his atlas and is depicted herein and is held by the Basel University Library.

Map image from "Abraham Ortelius," Wikipedia.org, https://en.wikipedia.org/wiki/Abraham_Ortelius#/media/File:OrteliusWorldMap1570.jpg.

Drake's circumnavigation and Pacific raids had enormous geopolitical ramifications. The Spanish ambassador in London, Bernardino de Mendozza's reported upon Drake's return that he might have found the Northwest Passage entrance into the Pacific.[45] In response to his return, Philip sent a 3,500 man force to fortify the Straits of Magellan.[46] The reason behind these erroneous assumptions and futile maneuvers was simple – Elizabeth and her Privy Council used their security apparatus to prevent any dissemination of this new strategic cosmographic knowledge regarding the southern extremity of the Western Hemisphere and the details of its northwestern coastline.

Bawlf recounts that "Immediately upon his [Drake's] return in 1580, Queen Elizabeth had ordered a ban on publication of any details of his voyage." Even by 1589 an account by English colonial propagandist Richard Hakluyt left out the details of Drake's trip by "official order," the modern equivalent of a government secret classification.[47] In 1593, Drake rewrote his account and presented it to the Queen requesting publication; it was again suppressed, "however, a carefully edited rendition of Hakluyt's shorter account was published instead." Bawlf speculates that a frustrated Drake was not completely circumspect with regards to his achievements and his hopes to secure his legacy led him to give some clues to his more learned colleagues. He notes,

> "But the cartographic information that he gave out privately to his friends, Ortelius, and others, much of it enciphered to comply with certain rules of

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[45] Bawlf, 4, in a letter to Philip, dated October 16, 1580.

[46] Edmundson, William, *A History of the British Presence in Chile: From Bloody Mary to Charles Darwin and the Decline of British Influence*, 14, Philip II had asked about chaining the Straights, but his Viceroy in Lima sent Don Pedro de Sarmiento y Gamboa to pursue Drake, and home to Spain to tender advice. Sarmiento recommended to Philip the naval force of 23 ships and 3500 men eventually sent in 1581. Also Portuondo, 195-8, and Bawlf.

[47] Edmundson, 10, notes "When the famous contemporary historian Richard Hakluyt published his *Voyages and Discoveries: The Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation* in 1589, there was an account of Drake's voyage, but no mention of the open water passage to the south of Cape Horn – Drake's Passage."

Taylor, *Late Tudor and Early Stuart Geography*, 18.

> secrecy, was designed to preserve knowledge of his discoveries, and has recently been deciphered to reveal the true extent of his voyage."

However, these clues did not openly expose the knowledge deemed secret by the Privy Council or give his friends enough detail to form a coherent and accurate global picture. Even thirty-two years after his death, when Drake's tract was published in 1627, the printed copy still omitted Drake's true northing.[48]

Despite Drake's tantalizing clues, friends of both the English state and its chief proponents of empire where kept in the dark regarding the true cosmographic picture which Drake brought home. Gerard Mercator, the Flemish cartographer and developer of the cartographic projection that bears his name was unable to accurately depict the globe in his subsequent reprints, despite close relations with men such as Drake and Hakluyt.[49]

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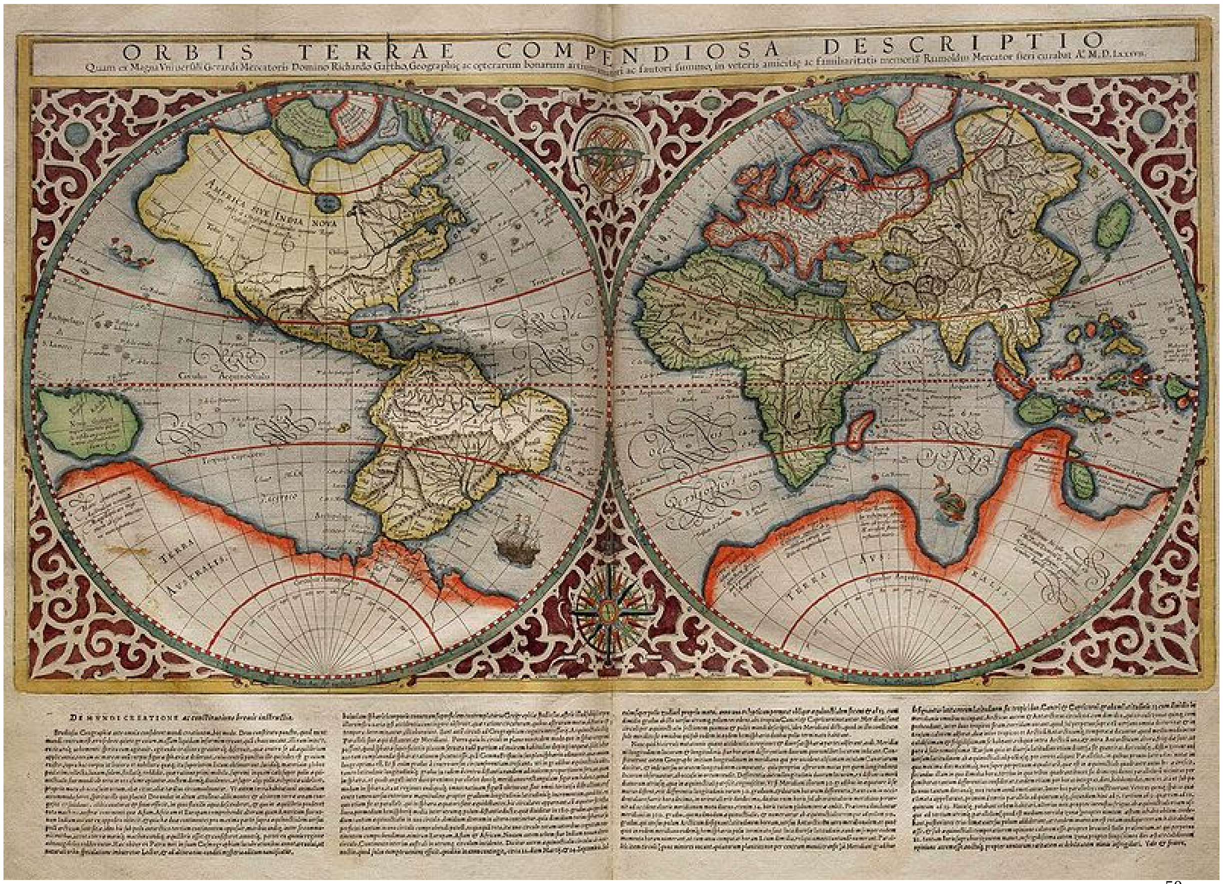
[48] Bawlf, 5-7.

[49] Hakluyt, 208-210, held Mercator in such high regard that he included a letter written in 1580 from Mercator to Hakluyt addressing the importance of English Muscovy Company exploration in the northern latitudes. Communication between Mercator and the English explorers and their backers was regular and friendly.



Map 6.2. Knowledge suppressed. Rumold Mercator's world map was drawn in 1587 and published in 1595.[50] Although based upon his father's (*Gerard de gemor*) map of 1567, none of Drake's critical geopolitical discoveries have been added to what was the state of the art world map (as opposed to navigational chart or Mercator projection) of the period. Drake's passage is missing, the South Pacific is only accessible westward through the Strait of Magellan, North America has not been reduced to its proper size, and the elusive Northwest Passage is still depicted.

As depicted in his son's 1595 reprint (drawn in 1587) shown above; the Mercator world map – as opposed to a navigational chart or Mercator projection with its parallel lines of longitude and latitude creating distorted land masses towards the poles and intended for practical navigation and maintaining heading by compass direction – was still essentially as out of date the day it was published as Ortelius' 1564 map of the world.

Explorers like Drake, Frobisher, and Grenville were also loyal soldiers of the Queen involved in a long undeclared war with Catholic Spain. The state would support their projects,

[50] "Antique map of the World by Gerard and Rumold Mercator," Sanderusmaps.com, https://sanderusmaps.com/en/our-catalogue/detail/166362/antique-map-of-the-world-by-gerard-and-rumold-mercator/.

providing even royal ships if needed, but the knowledge uncovered by those discoveries was controlled by the state security apparatus. Men like Drake would sponsor scientific research projects to enhance their piratical operations and in turn receive astronomical navigation education from England's leading cosmographers like Dr. John Dee or instrument makers like William Bourne, but all these activities and the results they produced had to be vetted by men like Walsingham before they could be disseminated.[51] Even military operations, like those conducted by Drake in 1587 against Spanish shipping at Cadiz, were coordinated through the office of Mr. Secretary. After conducting his raid, Drake reported,

> "Sir Francis Drake to Walsyngham. Believes the Spaniards will not trouble England suddenly, their ships and provisions had been so completely destroyed. Upwards of 60 hulks and fly-boats laden with provisions had been taken or burnt, and what they were unable to reach the enemy themselves had destroyed. The sickness of the soldiers and mariners is very great, and they desire much to return to England."[52]

By the end of the sixteenth century, England's oceanic program to include trade and its naval development were critical issues of state. The Elizabethan state has often been referred to as authoritarian and paranoid with incessant subterfuges, plots, tortures, and political executions. It is not surprising therefore that its oceanic program would be a product of this milieu. Sectarian divisions, foreign threats, and competing regal claimants representing different faiths heightened the mistrust and uncertainty of the age. Once power was obtained, men such as Walsingham built elaborate networks to retain it. England, a small nation facing continental armies of greater quality and size, relied upon prowess at sea for survival. As this requirement coincided with an explosion in nautical proficiency in the West, it is not surprising that the masters of the state would want to buttress their tenuous hold on power by acquiring, expanding,

[51] Deacon, 87.
[52] SP 12/202 f.8, "Sir Francis Drake to Walsyngham," June 2, 1587.

and safeguarding nautical knowledge, and the competitive advantage it provided, using their new security tools to do so.

However, the oceanic program was also a driver of increasing the size and scope of state security apparatuses. Maria Portuondo has noted that “Geographic knowledge was central to the budding Elizabethan program of territorial expansion.”[53] Richard Hakluyt and many other young educated gentry were sent to the continent (Paris in Hakluyt’s case) to search for Spanish and Portuguese cosmographic and nautical secrets. Walsingham and Burghley employed a large number of this newly educated, but unemployed young gentry and sons of wealthy merchants, sending them throughout Europe with specific instructions to learn about the navies, tradesmen, and cosmographic discoveries of their friends and foes alike. Lacking a large standing army or navy, England had very few other outlets for its idle gentlemen without property or prospect of inheritance. Having only its embassy in Paris for official activity, the Elizabethan government mustered more than young educated nobles for its ‘intelligencers.’ The spymasters also paid large numbers of tradesmen to gather what information they could while visiting foreign ports.[54] Since English foreign policy was in large part driven by exigencies of trade, this was both a logical choice and one that was particularly suited for discovering nautical secrets.

With a growing and developing fleet of merchant adventurers at sea, explorers regularly returning home, growing academic ties abroad, growing local craft development in ordnance and shipbuilding, and purloined intelligence coming in from a myriad of spy networks, the English had enormous amounts of nautical data to assimilate, process and put to effective use in their struggle for both political and mercantile advantage vis-à-vis their Western European neighbors.

[53] Portuondo, 264.
[54] Haynes, 13.

Even though the Iberian powers had a long experience with managing the inflow of new cosmographical data, Taylor rightly points out that,

> "In Spain and Portugal navigation to the Indies had settled down into a fixed routine, but in Elizabethan England men's minds were full of projects for colonization, discovery, and naval warfare. And some of them at least realized that the necessary improvement of methods was at base a mathematics problem."[55]

Elizabeth rejected the centralized control model the Iberians had adapted for managing the cosmographical, especially the Spanish institutional response to training/licensing pilots and directing the progress of navigation through a single institution like the *Casa de Contratación*.[56] But she did not free its independently produced product from either intellectual security vetting or material apportionment (to include payment of her share). As their initial motives for attacking the seas were different, even if they both evolved toward similar goals of colonial and mercantile expansion, England and Iberia's peoples created very different social institutions for managing the fruits of their respective oceanic programs.[57]

Sandman and Ash have persuasively argued that the English, rather than adopting the Spanish navigational program outright, actually adopted an 'idealized distortion' first presented by Sebastian Cabot, which was able to blend the new metropolitan cosmographic canon based upon celestial navigation and traditional chart and bearing seamanship of the North Atlantic. Cabot was fortunate to find an England with little surviving oceanic tradition; one that did not produce the factional infighting between

[55] Taylor, *The Haven-Finding Art*, 215.
[56] Ibid, 174, one English official [Stephen Borough] "made a powerful appeal to Elizabeth to establish a similar system in England. Perhaps it was as well that she did not, for as the century grew old the Spanish sailing methods became stereotyped and old-fashioned, while in England there was a rush of new ideas."
[57] Portuondo, 57, notes that "Not coincidentally, a similar surge in interest in astronomical navigation in late Elizabethan England answered similar motivations: a need to conserve profits by achieving certainty in navigation, a general excitement about overseas exploration, and a political will to expand beyond traditional borders."

pilots and cosmographers that was endemic in Spain's *Casa de Contratación*.[58] But he also found an England with a long tradition of independent tradesmen and one with a relatively small government compared to Spain. The English never nationalized their trade and exploration program in the Spanish fashion, preferring instead to control the sensitive knowledge product of their merchant adventurers with their budding security apparatuses; using censorship, sponsorship, investment, exclusive patents, chartered private monopolies like the Muscovy Company, charted mariner's guilds like the Trinity Houses, endowed university chairs focusing on nautical problems, espionage, and subterfuge, to both protect their nautical canon and to transfer the benefits of foreign canons to their countrymen.

As English forays into the Atlantic expanded, the product of intelligence networks became increasingly important to continued oceanic success. Cosmographical information, cartographic accuracy, astronomical prowess, applied mathematics, foundry technology, ship building techniques, sail design, hydrographic knowledge, theories on magnetic deviation, and tidal data all became essential inputs into the oceanic project. And as such, these items became both objects of the embryonic state security apparatuses and engines for their growth.

[58] Sandman and Ash, 814-815, Stephen Borough argued unsuccessfully in 1562 for the creation of an English Pilot Major despite previous arguments presented by eminent men such as Cabot and Hakluyt. The English had addressed the need for training pilots at mid-century by building their first joint-stock trading company from their merchant class, to defray risks, combine resources, and focus and direct their expansionist ambitions. With protection from local competition and explicit support of the Crown manifest in a Royal Patent for all northern trading and exploration to Cathay, the merchants named Cabot, governor-for-life of their Muscovy Company at its inception, and he promptly went about creating an English merchant marine based upon his conception of the proper balance between celestial knowledge, experience at sea, and leadership abilities. 830-831, footnote #61, the authors do reference Waters (83-84) and Hakluyt (1589, 519-52) noting that Edward VI granted Cabot a pension and the honorary title "grand Pilot of England. Although there is no evidence within this document or elsewhere, that Cabot was ever granted the office."

Dee, John, *The Perfect Arte of Navigation*, 1577, also calls for a "Grand Pilot General of England" in his bid for strengthening England's naval position. (Noted in Smith, Charlotte Fell, 43)

As we discussed in Chapter 5 (see footnote 69), Walsingham used young educated men like Hakluyt for gathering cosmographical and nautical intelligence across the continent. Taylor notes that this intelligence could be of the traditional variety sought in all conflicts (fleet sizes, sailing dates, armament, etc.), but also scientific. In 1577, the death of the last Avis king, Dom Sebastião at the Battle of Alcácer-Quibir in Morocco, initiated a dynastic struggle which effectively resulted in Portugal's absorption into Phillip II's Spain in 1580. The Portuguese 'Pretender' Dom António and his entourage fled to England, where they were extensively interviewed by Hakluyt. From those interviews, and innumerable interviews with returning English merchantmen and adventurers like Drake, Hakluyt acquired access to practical Iberian navigation secrets concerning their methods and trade routes; where his Flemish contacts, Rumold Mercator and Ortelius, provided him with theoretical insight.[59] Taylor observes that when Hakluyt published his *Voyages*, he was effusive in his thanks to Walsingham,

> "The Epistle Dedicatory to Sir Francis Walsingham sufficiently illustrates Hakluyt's charm and skill as a writer, and also displays his tact. … Finally the zeal of Walsingham for navigation is praised, and the encouragement that he has given to Hakluyt, both in regard to his past and present writings, is gratefully acknowledged, while the period is rounded off by a reference to the happy censorship of the *Voyages* by Dr. James, the Queen's Physician, under Walsingham's direction."[60]

This last comment is illustrative. Not simply did the state use the educated to gather navigational knowledge, and not only did they vet and edit its disbursement, but they also enlisted the highly educated and those close to the seat of power to conduct this censorship. Another learned

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[59] Taylor, *Late Tudor and Early Stuart Geography*, 7, these intrigues and their resultant Portuguese confidences set Hakluyt up for his eventual position as the first expert advisor to the East India Company (12-31-1600).

[60] Ibid, 15-16. Hakluyt was involved in almost every aspect of the English maritime program from spying to sponsoring colonies. Taylor notes that Hakluyt developed a plan to capture-colonize Magellan's Strait – based upon John Winter's (1579-80) voyage there in *Elizabeth* gleaned from Hakluyt's interview with Winter's steward Thomas Griggs – and recommended capturing the outlying Portuguese colony of St. Vincent (São Vicente) in Brazil (not far from modern Santos on the coast south of São Paulo) to serve as way-station and supply base for this Magellan colony. He also encouraged the search for a North-East Passage – for woolens trade with the Tartars (Muscovy market) and a new short cut to the Spiceries including the North-West Passage. He eventually becomes a leading proponent of colonizing North America.

physician close to Elizabeth also greatly expanded England's growing nautical cannon, but rather than censor knowledge, he actively sought ought resolutions to pressing obstacles confronting England's growing class of professional mariners.

William Gilbert – Magnetism and Practical Science

Elizabethan England focused its most learned minds towards the problems of the sea. As Taylor observes, "the seaman's problems of position-finding by compass direction, latitude, longitude, and the use of the sea-chart, were at that time problems which taxed the highest skill of the astronomer-mathematician."[61] William Gilbert (alternatively Gilberd), the Queen' Physician, was one of these leading minds. He was university educated at St. John's College, Cambridge, where he earned a B.A. (1560), Fellow (1560-1), M.A. (1564), mathematical examiner (1565-6), M.D. (1569), and finally Senior Fellow (1569).[62] He travelled continental Europe and in 1573 was elected as a Fellow of the Royal College of Physicians. His prominence was such that he was named 'physician-in-ordinary' to Queen Elizabeth. As we discussed in Chapter 4, Gilbert was one of the early supporters of the Copernican theory, at least regarding the proposal of an axially rotating earth and that his classic work *De Magnete*[63] was well regarded by his contemporaries and highly influential upon such luminaries of early science as Kepler and Galileo.[64] However, it is Gilbert's impact upon, and input from, England's mariners

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[61] Taylor, *Late Tudor and Early Stuart Geography*, 68. Her examples include Thomas Hariot (employed by Sir Walter Raleigh on his Virginia ventures), Edward Wright (sailed with the Earl of Cumberland to the Azores), Robert Hues (went into South Seas with Thomas Cavendish), Abraham Kendall (acted as skilled observer for Robert Dudley), Thomas Widdows (accompanied Henry Hudson on his last voyage), and Thomas Hood (designed instruments and charts, and lectured). We will address this linkage between England's intellectuals, modern science, and the oceanic program more thoroughly in Chapter 7.

[62] Mottelay, P. Fluery, "Biographical Memoir", ix, from Gilbert, William, *De Magnete*.

[63] The full title: *De Magnete, magneticisque corporibus, et de magno magnete tellure; Physiologia nova, plurimis & argumentis, & experimentis demonstrata*, 1600.

[64] Mottelay, xii, quotes Henry Hallam noting that "[William] Gilbert was one of the earliest Copernicans, at least as to the rotation of the earth, and, with his usual sagacity, inferred, before the invention of the telescope, that there are a multitude of fixed stars beyond the reach of our vision." Also see Chapter 4.

and his research that we will focus upon. His researches into magnetism were not conducted in a vacuum or to satisfy mere intellectual curiosity, but were purpose driven. Men like Leicester, Walsingham, and Burghley were not simply content to steal the nautical secrets of their European rivals.[65] They actively engaged the nation's leading intellects in the resolution of maritime problems, especially those concerning high latitude navigation and magnetic variation, encountered by the Muscovy Company's arctic explorers.

Gilbert conducted his research and experiments into magnetism with the inputs of mariners in mind.[66] In recounting the largely circumspect history of the lodestone discovered in iron ore, and of the introduction of the mariner's compass in the Mediterranean, Gilbert notes that "Sebastian Cabot first discovered that the magnetized iron (needle) varied."[67] This popular myth aside, – written records seem to grant the distinction of recording compass variation (a compass needle's inability to point to true or stellar north in certain locations) to Christopher Columbus[68] – it is significant to note that some of the important data used to generate Gilbert's theories were being supplied by oceanic mariners observing and recording natural anomalies. He expands on this theme,

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Koyre, 38, notes than neither the works of Giordano "Bruno not [Thomas] Digges succeeded in persuading Gilbert to accept, in its entirety, the astronomical theory of Copernicus of which he seems to have admitted only the least important part, that is, the diurnal motion of the earth, and not the much more important annual one. Gilbert, it is true, does not reject this latter: he simply ignores it, whereas he devotes a number of very eloquent pages to the defense and explanation (on the basis of his magnetic philosophy) of the daily rotation of the earth on its axis and to the refutation of the Aristotelian and Ptolemaic conception of the motion of the celestial sphere, and also to the denial of its very existence."

[65] Sonar, Thomas, "Navigation on Sea: Topics in the History of Geomathematics," 48, identifies both Blundeville's and Gilbert's first patron as the Earl of Leicester, while noting that they and their contemporary, the mathematician Thomas Hariot had connections to Sir Walter Raleigh.

[66] Mottelay, xvii.

[67] Gilbert, William, *De Magnete*, 8. Heathcote, 84, notes that this was a common and fallacious attribution.

[68] Heathcote, N.H. de Vaudrey, "Christopher Columbus and the Discovery of Magnetic Variation," *Science Progress in the Twentieth Century*, **27:105** (1932), pp. 82-103. His most convincing evidence is Columbus' diary entry from Thursday, September 13, 1492, "*En este dia, al comienzo de la noche, las agujas noruesteaban, y a la manana noruesteaban algun tanto* (This day, at nightfall, the needles deviated to the north-west, and on the morrow they deviated slightly in the same direction)." (83) He follows this up with an entry from September 17th which discusses variation in the expedition's compass needles corroborated by the pilots.

Taylor, *The Haven-Finding Art*, 172-173, disagrees and contends that the Portuguese noted and tried to compensate for magnetic compass variation before Columbus.

> "There are other learned men who on long sea voyages have observed the differences of magnetic variation: as that most accomplished scholar Thomas Hariot, Robert Hues, Edward Wight, Abraham Kendall, all Englishmen: others have invented and published magnetic instruments and ready methods of observing, necessary for mariners and those who make long voyages: as William Borough in his little work the Variation of the Compass, William Barlo (Barlowé) in his *Supplement*, Robert Norman in his *New Attractive* – the same Robert Norman, skilled navigator and ingenious artificer, who first discovered the dip of the magnetic needle."[69]

Gilbert addresses the local variation mariner's experienced with their compasses in Book IV, Chapter VIII of *De Magnete*. The Tudor mariner's compass of the day divided the 360˚ compass card into 32 equal points of direction, with a *fleur-de-lis* emblazoned on the card indicating north (see below). He explained in detail how to build a mariners compass (where a needle affixed to a direction card or compass rose moves within a box as opposed to a land based compass where the needle moves inside a ring of fixed directions) and he identified the four general European variation zones where compasses should be adjusted for a fixed amount to account for the variation (or deviation from true north) experienced by compasses.[70] He recommended no variation in the Mediterranean, ¾ of a point in the Baltic, 2/3 of a point for Russia, and a ½ point for the North Atlantic from Lisbon to England.[71] Gilbert provided a number of other instrument designs in his book as well, for using magnetic variation to determine latitude. We can also see the extent to which Gilbert relied upon sailor input, but at the same time lamented its inaccuracy as the title to Book IV, Chapter XIII so aptly illustrates,

> "Observations made by seamen commonly vary and are untrustworthy, partly through mistakes and want of knowledge and the ineffectiveness of the instruments, and partly because the sea is seldom so calm but shadows or lights may rest upon the instruments."

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[69] Gilbert, 14-15. William Borough (1536–1599) was the younger brother of Stephen Borough.
[70] Heathcote, 89-93, describes in detail the differences between land and mariner's compasses and that allowances for variation were in wide use in the sixteenth century on Flemish or Dutch vessels. Italian compasses did not account for variation, most probably because their local geography did not present this problem for technical resolution. His conclusion is that the Flemish mariners and instrument makers deserve the credit, derived out of a need to reconcile astronomical findings with deviant compass readings, for adapting their instruments to account for magnetic variation.
[71] Gilbert, 249-250.

Gilbert’s solution was tripartite. Send educated men to sea to gather better data, develop better instruments, and apply better mathematics to nautical issues. He was not alone in these beliefs.

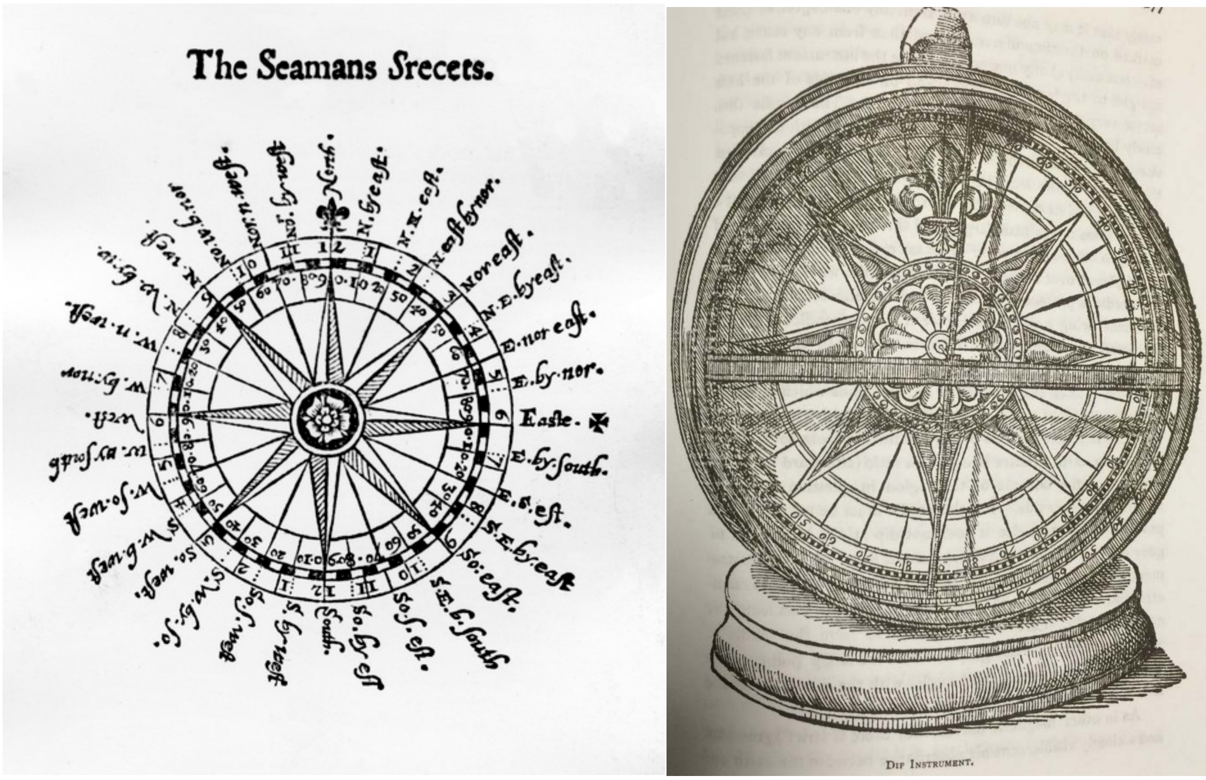


Figure 6.3. Tudor Navigation Instruments. The 32 points of a Tudor mariner’s compass from *The Seaman's Secrets* by John Davis, published 1594, is shown to the left. It is from the English School, (16th century). Medium: woodcut. Date: 1594. Provenance: Private Collection.[72] William Gilbert’s design for a dip instrument, presented in *De Magnete*, Book V, Chapter I is shown to the left.[73] This device is simply a vertical compass designed to measure compass inclination or magnetic dip (the incline at an angle from the horizon caused by the Earth's magnetic field not running parallel to the planet’s surface). Waters notes that Gilbert’s contribution to the original dip needle designed by Norman and improved by Barlow by enclosing it in a case and suspending it, was the addition of the brass horizon line and to describe it in detail.[74]

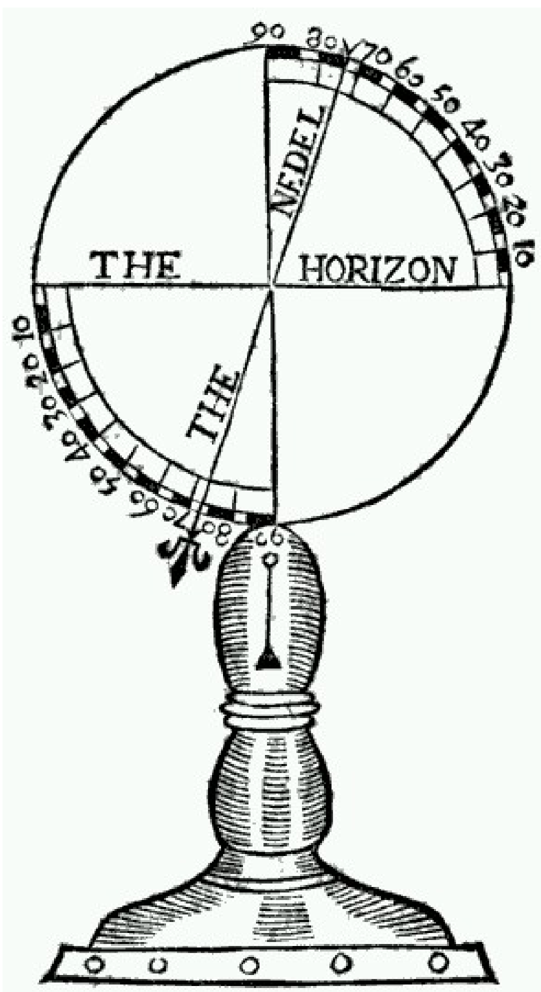
As William Gilbert noted himself, his work was built upon the work of not just natural philosophers and mathematicians, but upon the work of seamen and artificers.[75] As we observed in Chapter 4, Taylor notes that

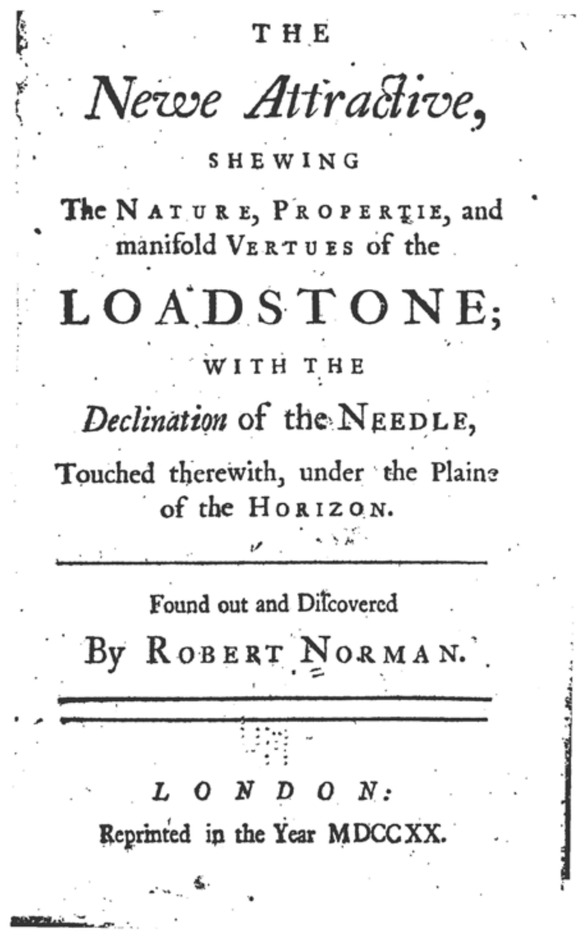
> “Gilbert’s researches upon magnets and magnetic bodies were begun about 1582, and so can hardly have been written without connexion [sic] with the publications of [Robert]

[72] Image from Wikimedia.org, https://upload.wikimedia.org/wikipedia/commons/2/25/Compass_thumbnail.jpg.
[73] Gilbert, Book V, Chapter I.
[74] Waters, 247.
[75] Ibid, 246, “There is little doubt that these two navigational works of Norman and of Borough inspired Gilbert’s researches.” William Barlow was also pursuing the same research, inspired by the same works, and communicated regularly with Gilbert.

Norman and [William] Borough, to which in fact the author makes abundant reference. … He devotes his final chapters to the application of his conclusions to those practical problems of navigation in which so many of his friends, including [the mathematician Edward] Wright, were interested. Gilbert boldly accepted the Copernican doctrine of terrestrial revolution, and thence proceeded to the theory that the earth was itself a rotating magnet."[76]

Robert Norman was a sailor, a navigator, and an instrument maker. In 1581 he published his discovery of magnetic dip and the designs for his device to measure it in *The New Attractive: Showing The Nature, Property, And Manifold Virtues Of The Loadstone.* [77]





THE

Newe Attractive,

SHEWING

The NATURE, PROPERTIE, and manifold VERTUES of the

LOADSTONE;

WITH THE

Declination of the NEEDLE,

Touched therewith, under the Plaine of the HORIZON.

Found out and Discovered

By ROBERT NORMAN.

LONDON:

Reprinted in the Year MDCCXX.

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[76] Taylor, *Late Tudor and Early Stuart Geography*, 68-69.

[77] Sonar, Thomas, "Navigation on Sea: Topics in the History of Geomathematics," 50, notes that "Already in 1581 the instrument maker Robert Norman had discovered the magnetic dip in his attempts to straighten needles in a fitting on a table." He also cites other claims on first discovery from another instrument maker, Georg Hartmann of Nuremberg.

Illustration of magnetic dip from Norman's pamphlet, *The Newe Attractive,* pg. 17.[78] Robert Norman's pamphlet from 1581 (the 1720 reprint title page is shown above) helps illustrate the ongoing feedback loop between the Elizabethan maritime adventurers and the London metropolitan intellectual elite. This book which first records magnetic dip on mariner's compass needles was referenced by Gilbert in his classic *De Magnete*, which in turn was in part presented to solve seamen's problems with compass variation and magnetic dip.

William Borough, as Eric Ash observes, "was no common seaman or ship's master; he was also a talented mathematician and was deeply committed to propagation of mathematical technologies of navigation."[79] As a Muscovy Company artic explorer he attempted to educate his contemporaries and the following generation of explorers. His work, *A Discovrs of the Variation of the Cumpas,* was also published in 1581 and was intended to address the second half of the problem he and his friend Robert Norman wanted resolved concerning the mariners compass.[80] This younger brother of Stephen Borough was a distinguished Elizabethan seaman, who was appointed Comptroller of the Queen's ships in 1580 and sailed with Drake in his famous raid on Cadiz in 1587, although their tactical argument led to Drake's accusing him of cowardice. He was acquitted by courts-martial of these charges and later given command of the galley *Bonavolia*. Borough, like his brother, was no dilettante. His concerns regarding navigation were practical, and his observations were gleaned in the frozen waters of the artic.

Despite ample evidence of maritime influences upon men like Gilbert and Barlow, and despite their specific attention to navigational theories and instruments, Gilbert's direct contribution to the effort of Elizabethan mariners is not universally accepted among scholars of this period. Lesley B. Cormack, in her *Charting an Empire: Geography at the English Universities, 1580-1620,* has observed that Gilbert

> "has been criticized for his impractical bent and the lack of any application of his magnetical knowledge to navigation, … [however] his work influenced [Henry] Briggs,

[78] Norman, Robert, *The Newe Attractive,* 17. Images from Wikimedia.org, https://en.wikipedia.org/wiki/Robert_Norman#/media/File:Norman_Robert_dip_circle.jpg.
[79] Ash, 154.
[80] Ibid, 153-154. William Borough traced his legacy back to Richard Chancellor's first voyages of 1553, where he served as a ship's boy at the age of sixteen.

> who followed him at St. John's, as well as scores of other young mathematicians eager to solve the theoretical problem of navigation at sea."[81]

However, it is noteworthy that even detractors to Gilbert's practical influence at the time, regard his impact upon the next generation of scholars who would mathematize navigation as significant. As just one further example of this, we can return to Cormack, who notes the mathematician William Barlow

> "is best known in geography for his two books on navigation, *The Navigator's Supply* (1597) and *Magneticall Advertisements* (written in 1609, published 1616). … Barlow's book, … dealt in a popular way with the innovative magnetical theories discussed by … William Gilbert in *De Magnete* (1600)."[82]

P. Fleury Mottelay, in his Biographical Memoir preceding his 1893 translation of *De Magnete*, notes that Gilbert decidedly was practical in the application of his theories, producing designs for astronomical and marine instruments,

> "He is, besides, the inventor of 'two most ingenious and necessarie Instruments for Sea men to find out thereby the latitude of any place upon the sea or land, in the darkest night, that is without the help of Sunne, Moone or Starre.' These instruments are described in Thomas Blundeville's quarto work entitled 'The Theoriques of the seuen Planets, shewing their diuerse motions … printed at London 1602.'"[83]

The astronomer and science writer Thomas Blundeville was not in the least ambiguous about Gilbert's practical contribution to Elizabeth's mariners,

> "Both these Instruments I receiued not long since from my deare friend M. Doctor *Gilbert,* for the which I most heartely thanke him, the inuention of which Instruments deserueth more worthie commendation and praise, than I am able any way to yeeld,

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[81] Cormack, Lesley B., *Charting an Empire: Geography at the English Universities, 1580-1620,* 86, notes in footnote #139 that "Francis Bacon criticized Gilbert (in *Advancement of Learning,* 64) for creating a philosophy from a lodestone." Perhaps this stemmed from professional jealousy. Mottelay, xiii, quotes Dr. Thomas Thompson's praise for *De Magnete* as "one of the finest examples of inductive philosophy that has ever been presented to the world. It is more remarkable because it preceded the *Novum Organum* of Bacon, in which the inductive method of philosophizing was first explained." Bacon's reproach in *De Augmentis Scientiarum* is also hyperbolic, "Gilbert has attempted to raise a general system upon the magnet, endeavoring to build a ship out of materials not sufficient to make the rowing-pins of a boat." Make what you will of the nautical analogy.

[82] Ibid, 218-219.

[83] Mottelay, xix, references "Bibliotheca Britannica," Edinburgh 1824, Vol. I, Authors, by R. Watt, pages 124 and 414. Blundeville's tract can be found online at http://quod.lib.umich.edu/e/eebo/A16236.0001.001?view=toc . His description of Gilbert's instruments and their use can be found on pages 279 to 292.

> hoping that all Sea-men will bee as thankefull to him as I am in heart and good will, for whose profit there was neuer inuented from the beginning of the world two such noble and necessarie Instruments as these are, and therefore worthie to be esteemed of all men accordingly."[84]

One instrument was used to determine latitude by using a moveable quadrant on paper. The other instrument was designed to measure compass needle declination (inclination references magnetic dip; declination compass variation) and thereafter used to ascertain compass variation. Blundeville notes that,

> "The manner how to vse the said Instrument, in seeking to know the variation of the Marriners Compas in any latitude, is the selfe-same which Robert Norman and Master Borrough doe set downe in the foresaid booke, whereunto I doe referre you, and so bid you well to fare."[85]

Unfortunately, these instruments and the attempt of Gilbert and his associates to use magnetic dip to ascertain latitude was misbegotten from inception since latitude bears no relation to the magnetic field of the earth.[86] Gilbert had assumed that he had discovered the secrets of 'magnetic navigation.' As we shall cover in Chapter 7, future theorists would speculate that mapping terrestrial magnetic variation could be used to unlock the much tougher navigational problem – ascertaining longitude at sea. Edward Wright, the renowned mathematician and author of *Certaine Errors in Navigation* (1599; 2nd ed., 1610) which for the first time detailed the construction of a Mercator projection, noted in his preamble address to Gilbert's *De Magnete*, "And thus, thanks to this magnetic indication, that ancient geographical problem, how to discover the longitude, would seem to be on the way to a solution." [87]

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[84] Blundeville, Thomas, *The theoriques of the seuen planets* …, 291.
[85] Ibid, 292.
[86] Sonar, 44.
[87] Wright, Edward, in his preamble Address to Gilbert, William, *De Magnete*, xxxix.
Gilbert addresses the topic himself in Chapter IX of *De Magnete*, he concedes that it was not possible in his time, but speculated that the problem was not theoretical, but rather instrumental, and could one day be remedied with more precisely manufactured devices, "if only fit instruments be at hand wherewith the deviation may positively be ascertained at sea." (254)

This effort would also be futile. However, what concerns us here is not the efficacy of Gilbert's magnetic navigation theory or his instruments, but rather their impetus and purpose. Nautical problems were driving scientific research in Elizabeth's England and her leading intellects where pushing back the frontiers of knowledge, using data inputs from these same mariners. Gilbert referenced Norman and Borough and mathematicians and astronomers referenced Gilbert and the mariners. Thomas Sonar in his article "Navigation on Sea: Topics in the History of Geomathematics," identifies the intricate relationships involved in just this example of the magnetic navigation dead-end,

> "[The mathematician Henry] Briggs was at the center of Gilbert's group. At Gilbert's request he calculated a table of magnetic dip and variation. Their mutual friend Edward Wright recorded and tabulated much of the information which Gilbert used, and helped in the production of *De Magnete*. Thomas Blundeville, another member of Brigg's group, and – like Gilbert – a former protégé of the Earl of Leicester, popularized Gilberts discoveries in *The theoriques of the seuen planets* (1602), a book in which Briggs and Wright again collaborated."[88]

Very close circles of policy makers, mariners, and scientists in Elizabethan England were pioneering the frontiers of the modern world with all the false leads and erroneous theories common to modern science.

The Gresham circle of Briggs and Gilbert was not the only operating working group either inside or outside the universities attempting to resolve England's pressing navigational problems.[89] The Queen's astrologer, Dr. John Dee was at the center of an extremely varied

[88] Sonar, 61-62, that the details required by Wright to complete the tables referenced above first appeared in his 2nd edition of *On Errors in Navigation* (1610).

Waters, 248, on the same topic, "Thus the coordinated efforts of four men of science resulted in their devising, out of a complexity of research and calculation, the simplest and most necessary aids for seamen. … Although … their labors were in vain."

[89] Sonar, 48, Henry Briggs, the premier mathematician in England in his day formed the Gresham Circle. It consisted of "true Copernicans" such as Gilbert, Edward Wright, William Barlow, and Thomas Blundeville. The later had contact with Dr. Dee as well. See previous footnote 64 presenting the caveats concerning Gilbert's Copernicanism.

intellectual and power circle that also bent its energies towards nautical issues. Dr. Dee and his circle however, did not limit themselves to experimentation and mathematics.

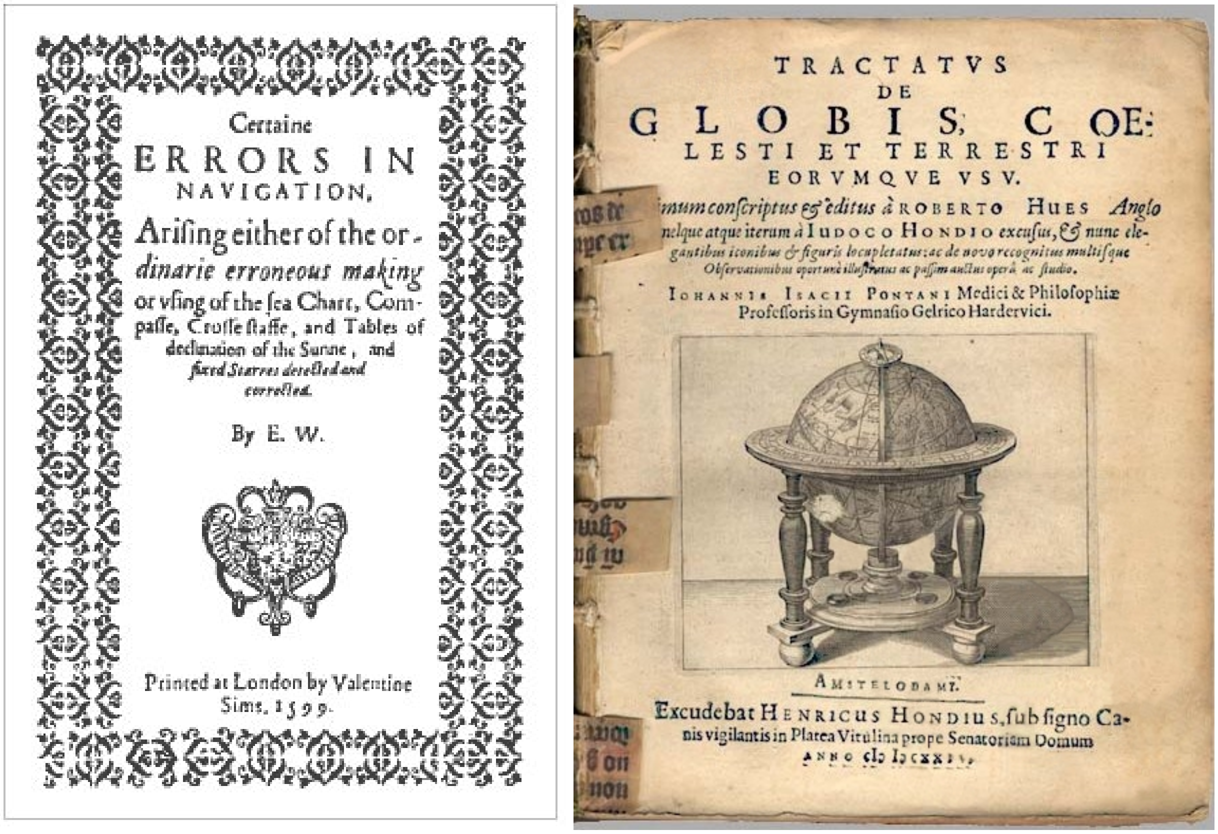

Figure 6.5. Cutting edge math and cartography in Tudor England. Edward Wright's ***Certaine Errors in Navigation*** (1599; 2nd ed., 1610) (left), first presented the mathematical basis for constructing the Mercator projection, and Robert Hues' ***Tractatus de globis et eorum usu*** (*Treatise on Globes and Their Use*) (right), explained the use and construction of globes, and more importantly was directed at English mariners as a polemic for adopting Iberian astronomical navigation techniques.[90]

Dr. John Dee – Cosmographer, Astrologer, Mystic, Spy

One individual that was deeply involved in all aspects of this sixteenth century saga and the English national drive towards mastery of the oceans was Dr. John Dee. This astronomer and

[90] "Edward Wright (mathematician)," Wikimedia.org, https://en.wikipedia.org/wiki/Edward_Wright_(mathematician)#/media/File:EdwardWright-CertaineErrorsinNavigation-1599.jpg, Wright's work provided a "reference table giving the linear scale multiplication factor as a function of latitude, calculated for each minute of arc up to a latitude of 75° … [or] a table of values of the integral of the secant function, and was the essential step needed to make practical both the making and the navigational use of Mercator charts."

"Robert Hues," Wikimedia.org. https://en.wikipedia.org/wiki/Robert_Hues#/media/File:RobertHues-TractatusdeGlobis-1634.jpg, Hues' work "was written to explain the use of the terrestrial and celestial globes that had been made and published by Emery Molyneux in late 1592 or early 1593, and to encourage English sailors to use practical astronomical navigation. … [It had] at least 12 other printings in Dutch, English, French and Latin."

astrologer of Welsh descent was both a mystic and a proto-scientist in an age where natural magic, philosophy, classical education, theology, and empirical observation were not clearly delineated and mingled pursuits into several or all of them were common among the small but growing intellectual class. An early student of mathematics and navigation, Dee used his classical education in Greek and Latin, and his deep appreciation of Welsh druidic astronomical accomplishments, to first learn the most advanced mathematical and navigation practice of the mid-sixteenth century, as understood in the universities of Italy and the Low Countries, and then to import this canon back to England, adding to its depth in the process. A student of Erasmus during his time in England and a contemporary and colleague of such pioneers in cartography as Gerardus Mercator at Louvain in Brussels, Dee was able to bring back to Cambridge the cutting edge theoretical knowledge, maps, globes, and astronomical instruments of the early Age of Exploration.[91] Dee served as a conduit and link between sixteenth century continental intellectual innovation and his benighted homeland. Although not a religious zealot, Dee was a patriotic defender of Protestant England, a fierce defender of his queen, and a vocal proponent of British Empire and a robust Royal Navy.

Dee was also an occultist, an astrologer, and as Richard Deacon argues, the leader of a private intelligence network dedicated to the preservation of his queen and the expansion of England's nautical canon. However, although Dee in the last third of his life, delved far deeper into mysticism than most of his contemporaries, providing fodder for his enemies in the process

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[91] Deacon, 19 and 23, "Dee kept in the closest touch with his old university [Trinity College, Cambridge] from Louvain and utilized his friendship with Mercator to launch a mathematical and navigational instrument-making industry in England, realizing in these matters his country was lagging behind the continent."

Smith, Charlotte Fell, *John Dee: 1527-1608*, 8, notes that "In May 1547, Dee made his first journey abroad, to confer with learned men of the Dutch Universities upon the science of mathematics, to which he had already begun to devote serious attention. He spent several months in the Low Countries, formed close friendships with Gerard Mercator, Gemma Frisius, Joannes Caspar Myricaeus, the Orientalist Antonius Gogava, and other philosophers of worldwide fame."

Suster, Gerald, *John Dee: Essential Readings*, 10, notes the irony that Dee's doctoral training and residence in Louvain from 1548 to 1551 was supported financially by both the Pope and the Hapsburg Emperor, Charles V.

– in an age where trial and execution for witchcraft was not an uncommon occurrence – it is important to state that the lines between pre-Baconian science and the supernatural where not very clear.[92] Dee was a practicing astrologer to the Queen herself, but he was also the confidant that trained her in astronomy and launched her lifelong interest in the subject.[93] Even families of impeccable Catholic lineage, like those of the Hapsburg Philip II and of the Avis monarchs lent great credence to the horoscopes cast on their behalf. The Church condemned black magic (demonically inspired), but embraced the study of white or natural magic. The difficulty lay in distinguishing between the two and that distinction often lay in the eye of the beholder. Dee's inability to ward off attacks suggesting he regularly crossed this line led to his arrest in 1555 during the reign of Queen Mary upon charges for casting enchantments (of which he was acquitted) and popular disfavor in his later life. However, in midlife, he was both revered and active in Elizabeth's long battle with Philip's Spain.

While at Louvain, Deacon contends that Dee started his intelligence network by gathering information from the resident court of Charles V in Brussels.[94] He overtly connected navigational prowess and national power and was determined to help England close this particular knowledge gap through both study and subterfuge. A prolific writer on mathematics, astronomy, navigation, and ship building, the early Dee was able to identify critical errors like that of Peter Perigrinus who assured English mariners that the compass needle turned to the celestial pole rather than the magnetic pole.[95] He would rewrite the canonical navigation books

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[92] Smith, Charlotte Fell, 61-62, "We must remember that in the early years of Queen Elizabeth's reign it was thought necessary to pass an Act of Parliament decreeing that all who practiced sorcery causing death should suffer death; if only injury was caused, imprisonment and the pillory should be punishment. Any conjuration of an evil spirit was to be punished by death as a felon, without benefit of clergy or sanctuary. Any discovery of hidden treasure by magical means was punishable by death for a second offense." She also notes, 17-18, that "astrology was a very essential part of astronomy in the sixteenth century."
[93] Deacon, 30.
[94] Ibid, 23.
[95] Ibid, 28, cites, E.G.R. Taylor, *Tudor Geography: 1485-1583.*

of the Muscovy Company in the middle of the sixteenth century that were first written by Robert Recorde.[96] Dee also advocated using signaling mirrors for controlling coastal defense vessels and for the adoption of naval telescopes long before their invention.[97] Taylor notes on all issues maritime, that Hakluyt and John Dee had become “the leading authorities of the day, consulted on each new overseas venture, the one expert upon the economic situation, the other for his unrivaled knowledge of cosmography.”[98]

Dee served the cosmographical role for England that his early Iberian counterparts fulfilled in their homelands by building navigational instruments and providing astronomical training, ephemerides, declination tables, and guidance in celestial navigation to some of England’s most renowned explorer/adventurers.[99] He trained and provided instruments for the chief pilot of the early arctic expeditions, Richard Chancellor, who opened up the White Sea routes to Russia. Stephen and William Borough were also his pupils, as were Martin Frobisher and Adrian Gilbert.[100] He sponsored and made the charts for the Northwest Passage voyages of Captain John Davis in 1585, 1586, and again in 1587.[101] Francis Drake conversed regularly with

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[96] Baldwin, Robert, “John Dee’s Interest in the Application of Natural Science, Mathematics and Law to English Naval Affairs,” in *John Dee: Interdisciplinary Studies in English Renaissance Thought; Volume 193 of International Archives of the History of Ideas*, edited by Stephen Clucas, 99, “Dee’s navigational teaching had initially followed the largely mathematical syllabus taught in London from 1547 by a fellow Welshman, Robert Recorde. From 1560 onwards Dee set about correcting some of Recorde’s textbooks for re-issue after Recorde’s death in 1558 because those texts were used to instruct the Muscovy Company’s pilots.”

[97] Deacon, 81.

[98] Taylor, *Late Tudor and Early Stuart Geography*, 2.

[99] Deacon, 28, notes in reference to navigational instruments, that “It was almost entirely through Dee, with the assistance of Humphrey Cole, that the English mathematical instruments-making industry was launched and laid the foundations for the voyages of discovery some ten years later.”

[100] Baldwin, 114, in discussing the instruction Dee gave to Frobisher, Christopher Hall, and Owen Griffen for their 1576 expedition, the author notes that all though the celestial navigation lessons were practical, most of math Dee tried to teach his pupils was both too erudite and of little daily value. However, the resources of his library at Mortlake were open to the men who borrowed one of Dee’s charts made by Ortelius.

[101] Deacon, 140-141, although all three expeditions failed in providing Elizabeth with a useable passage to China (Cathay), they dramatically increased the geographic knowledge Europeans possessed about the North Atlantic and the arctic Polar Regions. The Davis Strait was named after the leader of these expeditions.

Dee and Bawlf credits him with Drake's astronomical training that enabled him to establish the longitude on his North American west coast landfall.

Dee used his position as cosmographic expert to accumulate information of value to both his enterprises and to the English state. He was very active in debriefing returning captains and pilots of early exploration expeditions.[102] He was especially interested in compiling information about islands suitable as both bases and way stations and noted their strategic value in the project of empire building. The gathering of nautical intelligence for use by the English state and its private Merchant Adventurers was a lifelong project for Dee. Deacon observes that "Dee seems to have been one of the first to realize that to keep up with England's potential enemy Spain; the English must increase their knowledge of the new navigational techniques."[103] He adds, that

> "Not only the Elizabethan seamen came to Dee for navigation advice; those of other nations equally sought it, sometimes coming to Mortlake, at other [times] corresponding with Dee personally. Through his contacts with foreign sea captains Dee gathered a wide range of intelligence reports for Walsingham."[104]

It was at his home on the Thames called Mortlake that Dee presided over Tudor England's equivalent of a *Casa de Contratación.* Dee was not just focused on nautical issues; his interests spanned a wide gamut from medicine and mathematics, to philosophy and mysticism. By 1564,

> "Dee's circle at this time included many men who were playing their part in the development of scientific thought in England. With these men, Dee succeeded in building up an elite scientific circle, a group of friends and pupils who in effect formed the nucleus of a Royal Scientific Society."[105]

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[102] Deacon, 52 and on 88, "Not the least important part of Dee's Intelligence work was the collecting of information for Elizabeth's navigators and explorers."
[103] Ibid, 23-24, calls this first "industrial espionage."
[104] Ibid, 111.
[105] Baldwin, 99, Dee spoke of his library at Mortlake as 'Mortlacensi Hospitali Philosophum peregrinatum.'

Deacon, 70. In addition, he notes that, 36-37, "Certainly he [Dee] was one of the earliest advocates of the Copernican theory and the astronomical system which bore his name." Dee demonstrated, contrary to popular belief that comets were far above the moon. Dee "rescues" English astronomy from dark ages.

It was into this locus of scientific study that the secrets of all Europe's nautical programs flowed and from which England's own discoveries and insights were compiled. Deacon notes that Dee "made his own circle of friends and students at Mortlake into something very like an [scientific] academy and even more like a navigation college."[106] It was during this time at Mortlake that Dee penned his *General and Rare Memorials pertaining to the Perfect Arte of Navigation.*

Dee finished the first volume of this four volume opus in August of 1576. He wrote it for the ruling men of Elizabeth's England publishing only one hundred copies in 1577.[107] Dee presented the case for the establishment of a worldwide seaborne British Empire built upon commerce and policed by a '*Petty Navy Royall*' centuries before the nineteenth century *Pax Britannica*.[108] Even though this work cannot be considered a true navigation manual, some early elements of the genre are present and the importance of the book upon later Tudor and Stuart policy, although debated by some, is manifest.[109] Dee was overtly proclaiming a need to develop naval prowess in order to obtain national greatness, trusting in a navy, rather than fortresses;

> "To Conclude herein This Pety-Navy-Royall, undowtedly, will land the Realm in better stead, then enjoying of four such Forts or Townes, as Callys [Calais] or Bulleyn [Boulogne] onely, could do. For, this, will be as great strength, and to good purpose, in any Coast of England, Ireland, or Scotland, between us and the Forrein foe, as ouer Callys was, for that onely one place, that is situated in."[110]

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[106] Deacon, 76.

Baldwin, 115, notes Dee's collection of ship's compasses from across Europe and his early study of the origin of such instruments and the possible role that would play in magnetic deviation. Eventually Dee would train William Boroughs in theories that in addition to the latter's practice would help him note greater distortions when one approached the celestial pole (and thus increased the impact the magnetic pole's distance from same).

[107] Smith, Charlotte Fell, 39-40, notes that the second volume, The British Compliment, was written in the next four months, but never published for financial reasons. Much of it covers the "paradoxall" compass discussed below.

[108] Baldwin, 109, "By 1576-77 Dee's related ideas on the sea transport and navigational skills needed to transport mineral wealth were consolidated for limited publication as a vast tract called rather misleadingly, the *General and Rare Memorials pertaining to the Perfect Arte of Navigation.*"

[109] Suster, 37-38, notes that according to E. G. R. Taylor in *Tudor Geography*: "Dee gives the first English definition of the art of navigation (excluding Richard Eden's translation of Martin Cortes's *Art of Navigation*, 1561) and one that is hard to surpass."

Smith, Charlotte Fell, 44, "Enough has been said of this book, perhaps to show that it is a remarkable contribution towards the history of the navy and the fishing industries in Britain."

[110] Dee, John, *The Perfect Arte of Navigation (1577),* 9.

Dee wanted England secure and wealthy in a peace purchased by military invulnerability. A vigilant navy and active naval intelligence would provide this security;

> "It is an olde Proverb. A Sword, maketh peace: So, this Navy, by his present readiness, and the Secret of his Circuits, and visitations of sundry forreyn and homish Coasts, observed: will make the malitious murmurers, and privy malefactors, of all forces, to kepe in, and to forebeare their wicked devises and policies: which, otherwise, against us, they would adventure to execute."[111]

He laments the poor state of information about English home waters and recommends hydrographic expeditions to remedy this failing. Dee wanted England to protect its fisheries and he conducted an economic analysis of lost profits to justify the small naval expenditures required toward this end. Dee called for the establishment of a corps of sea soldiers a century before the establishment of the Royal Marines. Dee wanted a standing navy that supplemented a wartime fleet and he outlined not only the size, mission, and organization of the force, but also the tax policy needed to fund it;

> "And chiefly, Seeing Such a Pety Navy Royall, of Threescore Tall Ships, and eche of them, between eightscore and two hundred, Tun of Burden: And Twenty other smaller Barks, (between 20, and 50, Tun,) may be new made, very strong and Warlike: and all, well vittayled, for Six Thowsand, Six hundred, and Sixty Men: and those Men, Liberally waged: And both Ships, and Men, to all needful purposes, sufficiently appointed: and so maynteyned continually, and that, very Royally, FOR EVER: for les, then Two Hundred Thowsand Pownds Charges YERELY, sustained." [112]

Dee worked with Privy Councilors like Christopher Hatton (the head of the Queen's personal body guard and the patron to whom the book is dedicated) and Walsingham to convince the Queen to launch piratical expeditions against Spain and promote colonial and mining expeditions as well. He argued that England should openly proclaim its rights to the sea, and mocked the Iberian conceit that the non-Christian world was theirs to divide;

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[111] Dee, 15.
[112] Ibid, 18-19.

> "Can the Portugale King (by Popes Authority) cause the King of Spayn, to make his Navies and Armados, to forebeare coming within any portion of the East half of the whole world? (as to enjoy, or be maister of any Sea, Mayn, or Iland therein:) And also, will the King of Spayn, be contented , so, to condescend and allow unto the Portugale, upon condition, that other half of the (Westward)."[113]

In summary, Dee wanted England to assume a dominant role on the world stage and build a commercial empire underwritten by nautical excellence. In order to accomplish this, England needed to defeat Spain at sea by improving both its material fleet, but also by improving its nautical canon. This information had to be both produced by exploration and wrested from Spain.

Dee was not just a pamphleteer, a passive receiver of intelligence information, or an armchair cosmographer. As a young scholar abroad he established intelligence networks in Venice three years before Walsingham.[114] But Dee did not set himself up as a rival to Elizabeth's premier spymaster. Although providing information to Elizabeth of national import was an important requirement for a courtier trying to ingratiate himself to his sovereign, Dee was not a member of the Privy Council. He subordinated his intelligence activities under the patronage of the great men of state.[115] Deacon argues persuasively that Dee was leader of the intelligence post in Cracow enumerated as item number four in Walsingham's "Plot for Intelligence out of Spain."[116] Dee was abroad from 1583 to 1589 in both Prague and Cracow and Deacon claims that he was responsible for several intelligence coups in addition to providing information about Philip's Armada. "In 1584 Dee had been instrumental in obtaining evidence which showed that the Spanish ambassador in London was linked up in the Throckmorton plot,

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[113] Dee, 22.
[114] Deacon, 138.
[115] Smith, Charlotte Fell, 18, Dee relied upon the graces of Robert Dudley (before he became the Earl of Leicester) early in his career. Dudley had arranged for Dee to cast the horoscope selecting an auspicious coronation date for Elizabeth.
[116] Deacon, 231, this 1587 intelligence plan preserved in the state papers outlines Walsingham's plan for gathering intelligence on the Spanish Armada.

following which he was expelled."[117] Then in 1585, Dee helped uncover a Spanish plan to finance a French party of saboteurs intending to stop English ship building by burning the Forest of Dean which;

> "For centuries had been a main source of supply for Navy timber and most of the timber for the Elizabethan dockyards came from this royal forest. The object of this Spanish-inspired mission, which Dee had discovered in Prague, was to try and bribe foresters to burn down the trees."[118]

Dee was active as well in England's nautical explorations. Deacon notes that "In 1576 he accompanied Martin Frobisher on a secret voyage in search of gold in Labrador. … It is also true that this voyage was part of the quest for a North-West Passage."[119] In the *Perfect Art of Navigation*, Dee mentions having invented a "Paradoxall Instrument, and other Navigation matters."[120] David Waters examined Dee's claims about the 'paradoxal' compass and noted that, "Dr. John Dee made several obscure references to it in his writings, claiming to have been its inventor." It is only mentioned by Captain John Davis (northern explorer, author of *The Seaman's Secrets* and a pupil of Dee) prior to this time.[121] Waters concludes "that the paradoxal compass and the paradoxal chart were one and the same 'instruments,' namely a circumpolar chart."[122] Dee drew one such chart for Sir Humphrey Gilbert in 1582 which has survived, and which at the time was an English state secret. Ironically, this chart which greatly aided polar

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[117] Deacon, 7, Don Bernardino de Mendoza was at cross purposes with Alva in Flanders.
[118] Ibid, 8-9, this forest of 80 square miles was sizeable enough to supply the small Tudor navy.
[119] Ibid, 87, this voyage, financed by Edward Dryer was fifteen years in making and despite the initial excitement in London about Frobisher's black gold, was a bust.
[120] Dee, 16, this subject is addressed later in the text and in more detail in the second unpublished volume.
Baldwin, 100, Dee's claims "he had invented the circumpolar chart or "Paradoxall Compass in playne" in 1557, and describing his realization that a circumpolar sea chart could be of very considerable help in the assessment of real distance across the icy waters of the latitudes that Stephen and William Borough had been required to explore between 1556 and 1576."
[121] Cormack, 99, notes that "Since John Dee was much given to secrecy; it is not clear how many people knew of his innovative map projection. By 1595, at least Captain John Davis included this projection and instructions for navigating with it in *The Seaman's Secrets.* Davis may have relied directly on Dee's work … and he is known to have stolen several books from Dee's library."
[122] Waters, 209.

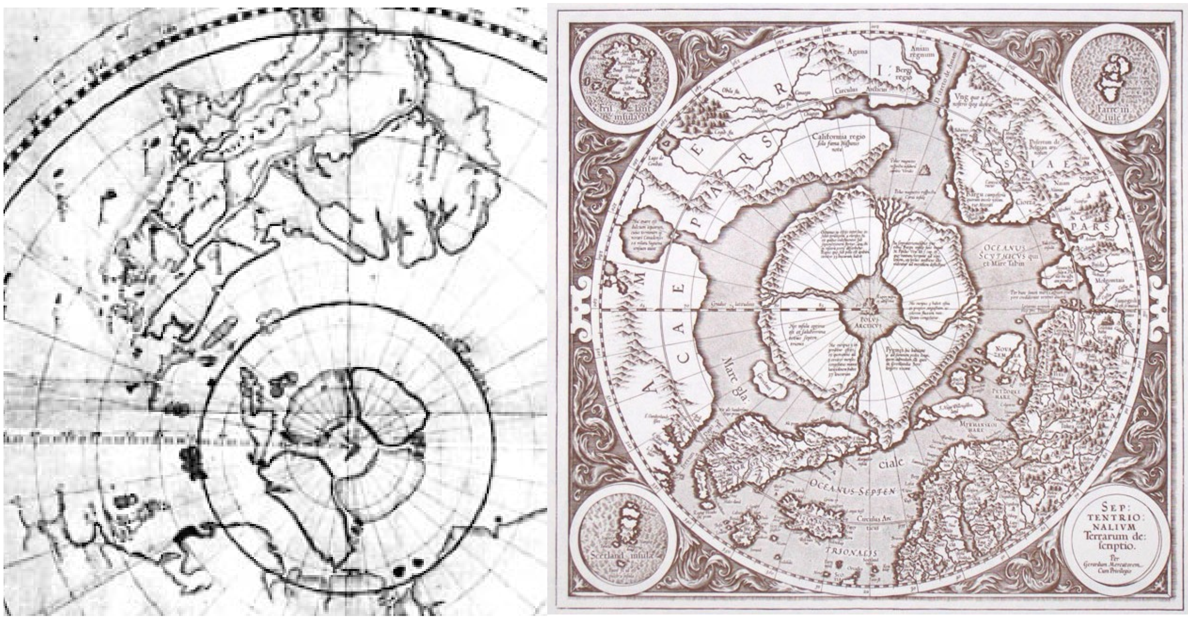
exploration by centering its radial view upon the pole, greatly diminishing the polar land distortions on conventional maps, was itself a Spanish state secret. Waters notes that,

> "Portuguese and Spanish hydrographers, faced with the problem of producing practical navigation charts of high latitudes in the southern hemisphere for Magellan's voyage of 1519-1522 around the world, had found the solution in the circumpolar chart. Thus, in fact, but almost certainly unknown to Dr. Dee, because of the veil of secrecy over such matters, his invention had been anticipated by more than thirty years."[123]

In the case of Dee, advancing his country's nautical ambitions came into collision with the secrecy interests of the state in a familiar echo of the Spanish experience illustrated by Sandman. In examining Dee's 1578 map (dated 1580) of Frobisher's northern discoveries, Baldwin is convinced that;

> "Dee was concerned with other related problems, such as the convergence of meridians, and how to present a navigator with the cartographic and toponomic realities. In doing this he thought not in the time-honored manner of the land lawyer, nor in compliance with the Privy Council's instructions that Frobisher's discoveries be kept secret, but more practically about how to present visually the problems of what compass course to steer, and how far along the North West passage were the newly discovered mines."[124]

[123] Waters, 210-211.
[124] Baldwin, 101.



Map 6.3. Mapping the poles in the Elizebethan Era. Dee's 'Paradoxal' Compass (left) proved to be a great aid to Elizabeth's polar explorers and was considered a state secret.[125] The polar projection centers a bird's eye view on the pole and typically ranges down to 50° latitude, greatly reducing the landform distortions common in early plan view maps. Ironically, the Spanish cosmographers aiding Magellan's circumnavigation had devised a similar solution for high latitude cartography three decades before Dee. Their state secret, and that of England's, soon became common fair, as Mercatur's 1595 circumpolar chart to the right attests.[126] Both charts depict both a Northeast and Northwest Passage and a possible polar route to China.

At age 54 (1581) Dee started crystal gazing and began writing the *Angelic Conversations*. Perhaps the most controversial and least understood phase of Dee's life, it is tempting to write this period off as deterioration. However, Deacon postulates that although Dee was a firm believer in the value he was generating in the uncovering of arcane knowledge through his séances, that these were also in part a cover for his espionage activities, especially while abroad in Eastern Europe.[127] However, the last twenty years of Dee's life were not ideal. Mysticism aside, we again perceive the conflict in state sponsored intelligence gathering, secrecy, censorship, and the pursuit of scientific inquiry. After returning to England in 1589, Baldwin contends "Walsingham was suspicious of Dee's plans and the use of his library, as Dee had been

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[125] Historymuseum.ca, http://www.historymuseum.ca/cmc/exhibitions/hist/frobisher/images/frmaf02b.jpg, also presented in Bourne, *A Regiment for the Sea*, Figure 13.
[126] "Arctic exploration," Wikimedia.org, https://en.wikipedia.org/wiki/Arctic_exploration#/media/File:1606_Mercator_Hondius_Map_of_the_Arctic_(First_Map_of_the_North_Pole)_-_Geographicus_-_NorthPole-mercator-1606.jpg.
[127] Deacon, 177, 216, he even notes the supposition of Robert Hooke who thought they were a form of cryptography.

a commissioner for the North West Parts and their Ores since 1577, and therefore had retained some vital documents."[128] After the defeat of the Armada, Dee would fade from the story of both England's nautical ambitions and the building of its secrecy apparatuses, but he had been integrally involved in both for the greater part of his adult life, helping England to catch up to Spain in nautical affairs and to defeat her at sea.

Connections

Iberia's lead in navigation in the fifteenth century was directly challenged from the north in the sixteenth. This challenge was first manifested by imitation and piracy. This policy was so successful that by the end of the century the new Spanish monarch reversed his father's long policy of state secrecy since the secrets at issue were common knowledge. In an ironic reversal of position, some of Philip II's military advisors even proposed that Spain bribe English pilots to enhance the proficiency of their fleet after the failure of the Armada.[129] England had subordinated its early oceanic program to political and security interests. The first trade expeditions of the Tudor period required official sanction, exploration of both a Northwest and Northeast Passage to China was only possible under Royal Patents, and like most privateer expeditions against Spain, both authorized and invested in, by the Crown. Private adventurers like Drake had to submit their records of discovery to state censors, but also were denied permission to continue their explorations when war with Spain became imminent, as it often did throughout the 1580s. For the time period when England had to learn from Iberia, this system produced results. However, by the end of Elizabeth's reign, England was no longer the laggard.

[128] Baldwin, 107.
[129] Haynes, 180-181, the Spanish Ambassador Mendoza even seems to have fallen for a ruse by English merchant intelligencers with Breton contacts with regards to the possible defection for better pay of fourteen English pilots displeased with Elizabeth's parsimony a year after the Armada victory.

She could no longer advance her nautical cannon by imitation and espionage. Her new race-built galleons, naval institutions, and gunnery and sailing proficiency put her ships on par with any at sea. England was even starting to advance the forward edge of navigational science. Taylor notes that "The introduction [by Thomas Hariot in 1600] of the 'true' chart, which any chart-maker could now draw with the help of [Edward] Wright's [trigonometry] tables, was the most important advance in navigational technique since the Portuguese astronomers had first taught the use of solar declination."[130] Moving to the front of the discovery curve, England and her scientists would now have to face new challenges as they embraced the required openness of Bacon's *Novum Organum*, while balancing the needs of state security.

This chapter noted that in order to safeguard national secrets and steal those of others, modern states develop institutions and participate in a number of activities including: restricting access to secrets only to trusted nationals, by export restrictions, through censorship, through state control of critical industries or intellectual disciplines, and through both domestic counter-espionage and foreign espionage. As has been illustrated, Elizabeth's Privy Council was active in all these regards, even though it did not nationalize the oceanic project or create monopolistic government bureaucracies to regulate cosmography and navigation; it often turned to Hapsburg Spain for exemplars to adopt, albeit with English coloring. Iberian government licensing of pilots and restriction of critical information and trades like instrument production to nationals had English counterparts in Cabot's Muscovy trading instructions and Elizabeth's restriction of wrought iron cannon sales to Catholic nations.[131] Walsingham's control of the press, printing,

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[130] Taylor, *Haven Finding*, 225, "And it coincided with the introduction of trigonometry into general use." This heralded the dawn of mathematical navigation enabled by advances in mathematics driven by direct navigational needs resulting from precision errors and spherical distortion of distance between lines of longitude at higher latitudes. That this was solved by a high latitude nation, closer to those distortions, makes it hard to escape some echoes of geographic determinism.
[131] Hakluyt, "Ordinances for the intended voyage to Cathay," 55-60.

and suppression of Drake's strategic exploits are similar in intent to Spanish restrictions on histories, cartography, and pilot's rutters, at the *Casa de Contratación.* Where the Spanish nationalized the institution of cosmography, Henry VIII took similar direct control of his nation's foundries. However, despite all these similarities, the English experience was distinctly different in its preference for the use of security apparatuses and indirect government influence to guide the oceanic project in stark contrast to Spain's direct government control.

Lacking large government bureaucracies, armies and navies (and the resources to support them), having a monarch with an abject hatred of debt and little tolerance for taxation, and possessing an independent trading class not easily shackled, the English chose to rely on security and secrecy institutions in their quest to first emulate the cutting edge oceanic programs of the day and later to protect the fruits of their own exceptional program. As stated in the beginning of this study, the concomitant rise of Elizabethan state security institutions and the expansion of the English overseas project were connected, directed in large part by the same actors, and mutually dependent. Their mutual growth was also a logical response to a pressing national objective coupled to limited resources and sectarian divisions that placed a precariously positioned monarch and her Privy Councilors in a desperate need for sound information.

However, England's move toward institutionalizing secrecy was not inevitable. It was neither driven by the peculiarities of its geography nor mandated by the fractured sectarian mix of its population. It was also not part and parcel of some overarching secular trend sweeping through northern Europe. French Huguenots and Dutch Protestants both expanded their nautical canon in the sixteenth century in an attempt to reap the same rewards flowing into Iberia from oceanic exploration. Both actively engaged Spain at sea in the same piratical war of attrition being fought by Elizabeth's Sea Dogs. However, French cosmographers like Jean Ribault and

Nicolas de Nicolay, and Dutch cartographers and printers had more access to Spanish academia and in the case of the Hapsburg province, direct connections with the leaders of Iberian Atlantic and Indian exploration.[132] The decision to embrace and grow security and secrecy apparatuses in conjunction with developing first a following, and eventually a leading edge oceanic program was made deliberately by Elizabeth and the leading men of her Privy Council. England's reliance on these tools more closely resembled the functioning of foreign policy in the Italian city states, despite the lack of any Atlantic program, than it did those chosen by their coreligionists in France and Holland. This choice may have suited England's mix of circumstance, but other choices were possible. If any of these choices would have produced the same spectacular results and catapulted England into its leadership position at sea is impossible to say.

Kristie Macrakis has noted that "When politics and science met, it [the intersection] accelerated the development of the science of secrecy." She presents the seventeenth century example "When William Perry presented a manuscript on shipbuilding to the Royal Society in 1665, Lord William Brouncker, the president, took it away and kept it because he said it was 'too great an Arcanum of State to be commonly perused.'"[133] In fact, there are quite a few papers in the Royal Society archives dedicated to nautical issues that were not immediately published for a myriad of reasons (see Chapter 8). There are documents on hydrology and meteorology (*Classified Papers*, Volumes IV-VI) from the mid-seventeenth century; a large volume (VII) on shipbuilding, geography, navigation and voyages (410 total frames); and a large volume (VIII)

[132] Sandman and Ash, 830, note that Henry VIII's Lord High Admiral John Dudley, Lord Lisle, sought to bring both French cosmographers to England in the 1540s. Lisle was also a prime mover in bringing Cabot to England.
[133] Macrakis, "Confessing Secrets: Secret Communications and the Origin of Modern Science," *Intelligence and National Security*, 197. The second quote is from pg. 191.

on astronomy.[134] In the early twentieth century, the renowned sociologist Robert K. Merton noted the inherent conflicts that exist between science and different social institutions. He observed that science could not prosper as a ward of the church, the economy, or the state. Despite the wide variety of state structures which supported the early institutionalization of modern science, Merton held that science had a distinct connection to social structures within a state and would function better if embedded within certain social structures rather than others.[135] It is one contention of this study that even though states and spies played demonstrably positive roles in helping Tudor England improve its early nautical canon, that the overall impact of state secrecy, censorship, nationality restrictions and the rest, retarded the development of cosmography in late sixteenth century Spain and would establish a link between state security and science in England that would not be entirely salutary.

England's lead in nautical affairs would grow in the seventeenth century. It would stop poaching upon the Spanish Empire and start building its own. The advantages it was developing within its institutions (legal, naval, scientific, and economic, etc.) would prove decisive in the European race for world dominance.[136] The security institutions that developed along with its oceanic expansion would also have consequence on England's future governance. The success and growth of England's aggressive oceanic program under Queen Elizabeth I was concomitant with the rise of its state security networks. These networks were used to both protect the

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[134] Collections from the Royal Society, *The Early Letters and Classified Papers, 1660-1740*, Project Editor, Paul Kesaris. The expression 'classified' is used in its organizational sense and not in the modern sense of restricted.
[135] Merton, Robert King, "Science and the Social Order," 328-334.
[136] Pomeranz, 166, rejecting exceptionalist arguments on institutional grounds, Pomeranz posits "Moreover, we do find some genuine European organizational advantages here – but they seem to be applicable to very few endeavors in the pre-1800 world besides war, *armed* long-distance trade and colonization." These advantages seemed to be very consequential. Pg. 62, more specifically to the cause of nautical programs, Pomeranz notes that "The relevant skills in which Western Europe led the eighteenth-century world were ones in which Britain led. One of these was mining, but the others are not ones whose relevance is immediately obvious: clock making, gun making and navigational instruments."

Protestant monarch from Catholic usurpation, and to obtain the maritime skills necessary to defeat Philip's Armadas and gain supremacy at sea.

However, long after England became dominant at sea, the legacy of its dependence upon security apparatuses, spy networks, and national secrecy ordinances, albeit in different form, and their relationship to science, would be felt. Returning to Merton, the scientific method and legend of pure unfettered science that would emerge in the seventeenth century, would state unambiguously that science depended on open communication and competition and that, "Secrecy is the antithesis of this norm; full and open communication its enactment."[137] But it is clear from this study that the ideal was never the case. Applied science and technology enhance the wealth and power of those who possess it. Accretions of this nature are rarely ignored by modern states. The emergence of the oceanic sciences and technologies that enabled the voyages of exploration, trade and colonization, were identified by Elizabeth and her Privy Council as indispensable properties of state to be protected, hoarded, stolen, or supported as circumstance dictated. In this they were truly modern.

[137] Merton, Robert King, *Social Theory and Social Structure*, 597.

CHAPTER 7.
English Guns, Science, and Society at Sea: A Study in Technological and Social Compromise from the Armada to the Glorious Revolution

The Armada Campaign as Inflection Point

Revisionist reproaches aside, Elizabeth's defeat of Philip's Armada of 1588, whether attributable to protestant winds or English gunnery, was decisive.[1] This is not to argue that from this point onward there marched a steady ascendancy of the Tudor Navy Royal to the Royal Navy of the Pax Britannia.[2] The amalgam private-public privateering navy of Elizabeth focused on *guerre de course* (or commerce raiding) did not evolve easily or smoothly into Nelson's line of battle fleet capable of global force projection and guarantor of open trade sea lanes, but the significant institutional structures to support a national navy, with the requisite support of the nation, its leaders, and a wide array of interests, did become part of the English system in these years.[3] The English people made a conscious decision to link their security, prosperity, and ambitions to the sea as the Tudor dynasty waned. This was no longer just the desire of the

[1]Glete, 160-161, "The Armada campaign of 1588 has perhaps more than any other naval event become part of mainstream historiography. Maybe the battle of Salamis 480 BC is comparable and for the same reason: it was a decisive battle between a huge empire (Persia) and an upstart sea power (Athens). … From a naval perspective the outcome was not sensational as it confirmed a century of technical, tactical and strategic change in warfare at sea, demonstrated in the Indian Ocean, in the Baltic, and already in 1545 in the Channel."

[2] James' I abandonment of the Tudor private-public naval coalition of swift commerce raiders, followed by Charles I emphasis on state power projection through large heavily gunned battleships, followed by the early interregnum policy of small craft designated for coastal defense and trade protection, illustrates the erratic course charted by the political masters of the young Royal Navy.

[3] Rodger, N.A.M., *The Safeguard of the Sea: A Naval History of Britain, Vol. 1, 660-1649*, 432. Rodger's general thesis is that a 'naval revolution' contemporaneous with the early modern 'military revolution' occurring in continental Europe came to fruition during Elizabeth's long reign. He contends that "Elizabethan government had created a consensus in favor of its unique hybrid form of sea power." His analysis leads him to suggest that "absolutist monarchy was essentially a system of government for mobilizing manpower rather than money." A modern navy on the other hand placed greater demands on government due to the huge capital outlays and myriad technical specialist communities involved. He goes on, "it may be suggested, what was needed was a system of government which involved the maximum participation of those interest groups whose money and skills were indispensable to sea power – not just the nobility and the peasantry whom absolutism set to work, but the ship owners and seafarers, the urban merchants and financiers, the industrial investors and managers, the skilled craftsmen; all the classes in short, which absolutist government least represented and least favored." He notes the long-term broad cross-sectional consensus required to field a successful navy and proposes that this lack of social structure was indeed critical in the failure of the naval aspirations of Spain in the sixteenth century, France in the eighteenth, and Germany and Russia in the twentieth.

coalition of Privy Councilor proto-imperialists, West Country pirates, and London merchants that had done so much to both sustain and manipulate Elizabeth's war effort against Phillip. However, Elizabeth's naval victory over Spain and the security of her throne were by no means assured as the Duke of Medina Sidonia rounded the Lizard and approached the Channel on the 29th of July, 1588 [Gregorian Calendar], at the head of Phillip's 'Invincible Armada'.[4]

Phillip II ruled the most powerful empire in Europe, his income was more than ten times that of Elizabeth's, his Spanish infantry tercios were the finest fighting force on the continent, and his commander in Flanders, Alexander Farnese, the Duke of Parma was acclaimed as the greatest general of the age. As a devout Catholic, Phillip had the financial support of the Pope and a ready supply of internal dissidents within Elizabeth's kingdom ready to rally to his banner. Valois France, the hereditary enemies of the Hapsburgs and Spain's only substantial continental rival, was convulsed in civil strife.[5] However, despite commanding considerable galley forces in the Mediterranean, and presiding over the combined oceanic merchant fleets of Spain and Portugal, Phillip II lacked both a navy and a coherent strategy for conquering England.

Elizabeth possessed a combined public-private force of about 40 large galleons. Phillip's only similarly modern vessels consisted of the *Guardia de Indias*, assigned to protect the yearly *flota*, and the few remaining serviceable galleons of the Portuguese royal fleet.[6] More significant, "there was no Spanish equivalent of the Navy Board, the Ordnance Board, or even

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[4] Alonso Perez du Guzman was the 7th Duke of Medina Sidonia, the richest feudal landowner in Spain. He was an accomplished administrator, but was not a proponent of Phillip's plan which he inherited upon the untimely death of Don Alvaro de Bazan, the first Marques de Santa Cruz, Spain's greatest admiral, a hero of Lepanto, and the victor of the battle of Battle of Punta Delgada, where he defeated a larger French fleet and secured the vital Azores for Spain. As the hub along the Atlantic trade routes, control of the Azores meant control of new world trade.

[5] Referred to as the [Eight] French Wars of Religion, fought between French protestants (Huguenots) and Catholics from 1562-1598; France did not reassert itself back upon the world stage until the and ascension of the Bourbon dynasty under Henry Navarre (Henry IV), his conversion, and the proclamation of the Edict of Nantes which affirmed France's Catholicism, but also protected the rights of protestants. The cynical conversion, heralded by Henry's possibly apocryphal quip, "Paris is well worth a mass," alienated his erstwhile ally Queen Elizabeth.

[6] Fernández-Armesto, Felipe, *The Spanish Armada: The Experience of War in 1588*, numbers nineteen galleons available to Phillip, nine from Portugal (the superior group), and ten from the West Indies flotilla.

the Privy Council. … There was no navy, no dockyard, and no naval administration."[7] Phillip would have to get his army to England by assembling the disparate armed merchant fleets of his far flung empire and provision this immense force by taxing the limited domestic economic capacities of feudal Spain and his reluctant dependencies. In this effort he was fortunate to have tapped the great ability and energy of the Duke of Medina Sidonia, but even his renowned administrative abilities could not overcome the structural deficiencies, medieval privileges, and limited production capabilities of the agrarian kingdoms of sixteenth century Iberia.

To compound his logistical and naval shortcomings, Phillip II saddled his field commanders with a vague strategic plan and without a sole commander in charge on the scene. The Marques de Santa Cruz had proposed a naval strategy requiring the capture of a West Country or Irish port, sea lines of communication to Spain, a large combined fleet of sailing ships and galleys, and a large amphibious invasion force. The costs of his plan were extraordinary. The Duke of Parma proposed an invasion launched from Flanders without the benefit of a fleet; in his plan the Armada would fulfill a diversionary role and lead the English fleet westward. He would rely on transport craft and secrecy for his crossing. The Duke of Medina Sidonia recommended reviving the Spanish Channel fleet, but cautioned that its size would have to be immense.[8] Others proposed invasions of Ireland and Scotland respectively. Phillip settled on an amalgam of the first three proposals. Unfortunately, there was little specificity on to how the Spanish invasion force and fleet were to meet with Parma's invasion force. Parma was to command the invasion, but the fleet would remain under naval command. In the end a poorly provisioned fleet, without a local operating base, shorn of its galleys (as it

[7] Rodger, *Safeguard*, 255, "all chains of command and responsibility met in the person of the 'bureaucratic king' himself."

[8] Ibid, 256, notes that Medina Sidonia cautioned Phillip that the English strength was primarily seaborne and that overcoming this threat would require large numbers to overcome qualitative differences. As a long standing naval administrator in Andalusia, he was well aware of the advances the English had made during Elizabeth's reign.

would prove, the only Spanish vessels capable of providing Parma's forces protection in the shoal waters off the Dutch coast), and lacking a field commander empowered to dictate joint operations between Parma and the naval force, proceeded into the Channel with the intent of forcing its way toward an expeditionary force attempting to board exposed and improvised transport vessels on an unfriendly Dutch coast. Juan Martínez de Recalde, the commander of the fleet's vice-flagship, notes that the Armada was launched 'in the confident hope of a miracle.'"[9]

The English had competing strategic visions as well, roughly offensive and defensive in nature. They could sally out to sea and attempt to hit the invasion fleet in the open sea, or better yet, in port or off Portugal – a dubious proposition in a day of limited intelligence, visual communication, and poor seakeeping capabilities – or they could concentrate the fleet opposite Parma and hope to stop the invasion with a single decisive sea battle. In the end, poor spring sailing conditions in the Atlantic and the ensuing reality of two enemy forces at opposite ends of the Channel required them to split their fleet and deal with both threats in home waters.

Each side knew the tactical strengths and fighting style of their opponent. "The Spaniards were well aware that English tactics were based on gunnery and that the English would not attempt to grapple or board."[10] Six years earlier, Santa Cruz, a hero of Lepanto (1571), had led the outnumbered Spanish armada sent to retake the Azores from the French navy. The core of his force was the eleven Portuguese galleons recently acquired by Spain. However, despite the superiority of his galleons, it was the Spanish infantry that won the battle of Punta Delgada, and this victory confirmed the dominant infantry paradigm of Phillip's admirals.[11] The

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[9] Fernández-Armesto, *Armada*, 42.
[10] Ibid, 114, adds "yet all Spanish thinking about the likely course of any battle assumed that only grappling and boarding could be decisive."
[11] Guilmartin, 155, "While the major warships on both sides were amply provided with cannon, it was a battle of boarding and counter-boarding that was decided by small arms, edged weapons and valor."
Konstam, *Sovereigns*, 174.

Spanish understood from years of English piratical depredations in the Atlantic and Caribbean that the new English ships were faster and more heavily gunned than their own, but they were convinced that if they kept their ships in tight formation and forced a melee upon the English that their quantitative and qualitative superiority in infantry would be decisive. This was not an unreasonable supposition, for as Jan Glete notes, up until this time there was no "instance of a fleet with superior gun-power defeating a fleet with a superior army," at least in European waters.[12] Additionally, the threat to sailing ships that gun armed galleys posed, and which inspired the development of the galleon (see below), was thought waning, possibly due to erroneous conclusions drawn from Drake's apparently easy destruction of them during his 1587 Cadiz raid.[13] The English in effect were looking past the current state of technology to its promise; the Spanish were making a rational assessment of that same technology based upon experience and concluding that it was not yet paradigm shifting.

This Spanish social dynamic placing aristocracy and their infantry above mariners and their skills also had a decided impact on the efficiency of the ships as fighting machines, and was a large impediment to making any radical change in their naval tactics.[14] The Spanish ships carried mariners that were commanded by their captain. A parallel chain of command existed on

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Fernández-Armesto, *Armada*, 135-144, despite the example of Spanish ships' effective fire at the Battle of Terceira (Punta Delgada), and warnings to Phillip from Santa Cruz about English gunnery, Spain was still committed to concluding a naval battle with boarding tactics. The author references a 1587 Spanish manual published in Mexico, Diego García del Palacio's *Instrucción naútica para navegar*, which asserts the infantry paradigm. This paradigm was confirmed with the allocation of only one gunner per gun in battle. The Spanish doctrine provided the one man to fire the gun while the infantry fought on deck. Reloading was not contemplated.

[12] Glete, 144, caveats his assertion, "The Portuguese in the Indian Ocean had, in fact, already demonstrated this in the early sixteenth century, but their experience was apparently not regarded as relevant in wars between European states. The Portuguese themselves did not take part in the European wars."

[13] Fernández-Armesto, *Armada*, 128, "galleys were momentarily unfashionable for northern warfare … perhaps [due to] … their failure against Drake's galleons in the bay of Cadiz in 1587; but on that occasion had been hopelessly outnumbered and unsupported by larger craft."

[14] Glete, 161, it would in fact take the massive trauma of the Armada defeat for Spain to radically change both her resistance to maintain a standing navy and building this navy around ship-killing gunnery. "Spain radically changed her naval policy after 1588 and built a large state-controlled navy, the largest battle fleet that had existed in Europe up till then. This fleet has received little attention from historians."

each ship whereby a noble born officer commanded the infantry. The gunners were of a yet another distinct group. This lack of unity of command aboard ship and common purpose among the crew gave the English a distinct advantage afloat where one man commanded and every crew member was tasked with fighting the ship.[15] The English ships were handled better and had rates of fire four to five times greater than their Spanish counterparts, illustrating that efficiency of technology is highly dependent upon the social milieu.[16]

The English had developed some technical advantages in their ships which we will discuss below, but they also had developed small technical innovations in their gun mounting that would add demonstrable efficiency to their rate of fire and hence their combat effectiveness. The English added recoil ropes, elastic fittings, pulleys, and wheeled trucked carriages to their guns and these innovations when combined with crew organization and training, and over-all ship up-gunning, made the medieval practice of a heavy single pre-boarding bombard blast seem antiquated.[17] The English could attack while bearing down on the enemy, shear off, reload, and head about for another attack three to four times in an hour.[18] This is of course a very slow rate of fire juxtaposed with the ship-killing broadsides of Trafalgar where well trained English crews could fire three shots in five minutes. But in the late sixteenth century, this rate of fire was

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[15] Guilmartin, 161.

[16] Fernández-Armesto, *Armada*, 165, in his revisionist defense of the Spanish concedes a rate of three times as fast. He also notes, 158, that the English practiced gunnery daily (although dismissing their effectiveness), something the Spanish did not do. The English handled their more maneuverable ships better than the Spanish handled their "over-masted" and "top-heavy" ships. He notes, 151-152, "that in the competition for the weather-gauge … the English [were] uniformly successful. … [and that] It was the inferior sailing qualities of the Spanish vessels that prevented the Armada from recovering the initiative" at the Battle of the Gravelines on August 8th.

[17] Konstam, *Sovereigns*, 201-204, and 214, far superior to Spanish: triple to quintuple rate of fire.

Guilmartin, 162, for the heavy guns recoil ropes and four wheeled carriages capitalized on the ballistic force of the firing gun to propel it back inside the gun port so that it could be loaded from the inside of the gun deck. Previous practice featured two-wheeled carriages similar to land artillery pieces where the guns were lashed in place and once fired, only reloadable from outside the ship. By the 1630s all the guns used recoil loading.

Glete, 158, notes that "the gun armament of the two contending fleets gave the English a marked quantitative advantage and this seems to have been increased by a qualitative advantage in gun-handling and in the ability of ships to maneuver into a favorable position for a gun-fight."

[18] Rodger, *Safeguard*, 270, gives an aggregate ship usage of one to 1-1/2 shots per hour per gun for the English compared to one shot per day on average for the Spanish.

unparalleled. N.A.M. Rodger, a preeminent historian of the Royal Navy, notes how the English repeatedly used line-ahead gun strike tactics while bearing down from windward. In these attacks whereby the ships struck in succession, he notes that even though each gun aboard was fired independently, the master gunner conned the ship into action in order to maximize the effectiveness of the guns. The English guns were themselves more maneuverable within the ship because “The English used compact ‘truck’ gun carriages designed to allow their guns to be canted round (‘bowed’ or ‘quartered’ in the terminology of the time) to fire nearly forward or aft as possible.”[19] This deference to warrant officers (the master gunner) in battle was itself emblematic of the emerging English social structure on board that placed primacy upon technical skill in critical situations, rather than deferring reflexively to aristocratic birth or military rank. The Spanish knew of these technical innovations, for they had captured English guns and carriages at the battle of San Juan de Ulúa almost two decades earlier, but their tactical paradigm was confined to the single broadside followed by boarding, so they did not incorporate these innovations aboard their ships. They entered the Channel prepared to close with and out-fight, not out-shoot the English.

While off the Lizard, Medina Sidonia assembled his fleet in a crescent formation with his most able warships in the van and on the wings deployed to protect the more vulnerable and numerous hulks and carracks of his fleet. For the next nine days the greater part of the English fleet led by Lord Charles Howard of Effingham, harried the Spanish as they proceeded eastward through the Channel. The Spanish formation held despite improving tactical adaptations by Howard including shortening his gunnery range and the division of his force into four attack

[19] Rodger, *Safeguard*, 265. He elaborates further upon the ascending social status of master gunners, Rodger, *Command*, 51, and notes that they were “in the seventeenth century often of better birth and education than the other warrant officers, sometimes a candidate for lieutenant or even captain.” In the emerging English navy, warrant officers, rather than being a technical specialist stuck between the common mariners and the officers, could through their own efforts, elevate themselves.

squadrons.[20] The English had prevented Medina Sidonia from bottling them up at Plymouth, in threatening the Solent by preventing an assault on the Isle of Wright, and Drake even succeeded in capturing a stranded payroll ship, but they could not prevent the Spanish from reaching Calais. Howard was finally able to scatter the Armada with a fire ship attack launched against its night anchorage on August 7th and he then attacked them vigorously the next day as they tried to reform. The wind and battle drove the Armada too far to windward to affect a union with Parma, whose expeditionary force and transports would have been vulnerable to Dutch attacks. Medina Sidonia could not enter the ports held by Parma because the Spanish ships drew too much water to navigate the shoals.[21] The Spanish admiral, having failed in joining Parma, then made the fateful decision to return home by circumnavigating the British Isles. The toll of nine days of battle; depleted and rotten stores; and Atlantic gales finished the job Howard had started.

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[20] Rodger, *Safeguard*, 267-268, Emulating the Spanish organization, Howard divided his force into four squadrons commanded by himself, Drake, Hawkins, and Martin Frobisher. Howard was even empowered to personally knight "Hawkins, Frobisher and several of his captains," for their conduct.

Guilmartin, 177, contends that the experiment with gunnery range was conducted by Drake on August 3rd and 4th.

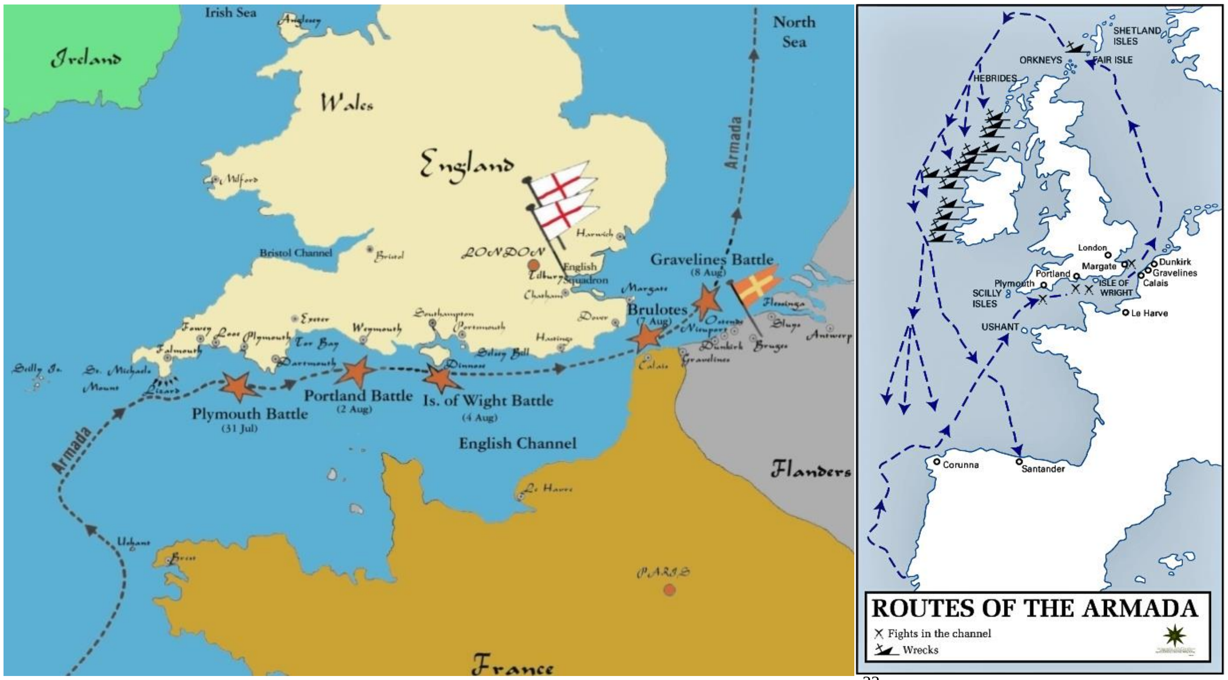
Fernández-Armesto, *Armada*, 171, notes that the superiority of English gun mounting technology was in fact offset by the superiority of Spanish gunpowder. He contends that the English powder was so poor that the effective range of the guns was reduced from 1,000 yards to 100 yards, and necessitated ranging much closer into the Spanish formation to effectively injure the Spanish ships.

[21] Fernández-Armesto, *Armada*, 127, notes that once again galleys could have bridged this gap, but like so much of Phillip's plan, the coordinating details of linking the Armada with the Flanders expeditionary force were not well coordinated or even practical.

Glete, 159, adds that "the enigma of the Spanish planning is why they brought with them only four galleys when they actually had at least 80 galleys in the Mediterranean. … Both the lack of light forces and inferiority in gun-power had doomed the enterprise to failure."

Rodger, *Safeguard*, 267-268, notes that Santa Cruz "had insisted all along that they would be essential." He reserves his 'doomed to failure' decision to Phillip's forbidding independent landings apart from reaching Parma.

Fernández-Armesto, *Armada*, 239, concurs, arguing that "the main weakness of the Spanish tactical plan: the failure to provide a safe haven or refuge for the Armada in northern waters." This lack of a conquered port in effect forced Medina Sidonia to sail north after the battle of the Gravelines.



Map 7.1. The route and destruction of Phillip's Invincible Armada of 1588.[22] Despite being beset by a lack of supplies (aggravated by Drake's 1587 raid on Cadiz), Atlantic storms, and the need to protect his weaker vessels, the Duke of Medina Sidonia was able to bring his fleet into the channel at the end of July and to proceed to within 25 miles of the Duke of Parma's expeditionary force. Constant English hit and run tactics, poor coordination with Parma, the threat of Dutch attacks at the embarkation point, the lack of inshore coastal warships suitable for the Flanders shoal waters (galleys), and finally Lord Howard's fire ship attack, forced the Armada off its station and into the North Sea. Medina Sidonia's fateful decision to return home by circumnavigating the British Isles and Atlantic gales finished the work which the English started. A broken and scattered Armada limped back into Spain.

A deeper examination of the Armada campaign and the technology used by both sides indicates that social factors – societal structure and military doctrine – were driving the technology developed for use at sea. The English maritime establishment of pirates and traders independent of the feudal aristocracy were creating technological artifacts that placed primacy upon their skills and ambitions. Since the 1570s John Hawkins ran a ship building program aimed at commerce raiding. The 'race-built' galleons he and his contemporaries built were fast, maneuverable, and heavily gunned. They sacrificed cargo and troop carrying capacity for

[22] "The 'Invincible' Armada," Tudorplace.com., http://www.tudorplace.com.ar/Documents/defeat_of_the_armada.htm and "Spanish Armada," Wimimedia.org, https://en.wikipedia.org/wiki/Spanish_Armada#/media/File:Routes_of_the_Spanish_Armada.gif.

gunnery.[23] The ships were nimble and suitable not just for harrying tactics in home waters, but also for independent cruises. They were not ideal for blockading an enemy port for long periods of time or for delivering troops abroad. The Spanish ships on the other hand, were built, manned, and gunned primarily to deliver aristocratic led infantry to battle, or to transport silver from the New World back to Spain. Their ships' high walls and their gun placement were designed to tip the balance in the on-deck infantry battle they viewed as both inevitable and decisive. It was social shaping of technological artifacts rather than technological determinism that created the stark differences in the two forces that clashed in the Channel. These late sixteenth century actors were operating in a world with very few barriers to technological transfer across borders; they both chose and enhanced the available technology they wanted to rely upon and make determinative. They supported this technology with institutions and command structures that both reflected their social hierarchies and their national aspirations. When the two forces met at sea, the ships designed for and by mariners won.

The Ascendancy of Northern Protestant Navies and Mathematical Navigation

The destruction of the Spanish Armada did not end Phillip's war with England, diminish Hapsburg power on the continent, or dissolve the Iberian global empires. Elizabeth authorized a disastrous private English expeditionary fleet against Spain in 1589 and Phillip organized several further invasion attempts. Within five years, the Spanish built the largest standing navy of

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[23] Konstam, *Sovereigns*, 184, "Race-built Elizabethan galleons – were purpose-built to combine speed, maneuverability, and firepower. These represented a development of naval warfare – the prototypes of the ships of the line that would dominate the age of fighting sail for more than two centuries." Additionally, 188-189, they had a 3:1 beam ratio, double the amount of guns for ships their size, a single continuous gun-deck, and finally, pre-copper sheathing to combat teredo worm (*Teredo Navalis*) and dirty bottoms (which decreased speed).

Fernández-Armesto, *Armada*, 155, Hawkins pursued construction of "long, low, narrow centrally masted, and therefore fast galleons that were best suited and best favored for Atlantic conditions" almost fanatically. 157, English ships were designed as gun carriers, where the Spanish designed troop-carriers. 161, The English guns were heavy (for killing ships) and low (for hitting hulls); whereas the Spanish were lighter and placed higher (for sweeping decks and killing infantry).

heavily gunned warships in the world, but this did not stop the English from seizing Cadiz in 1596.[24] Within decades, the Spanish attempt at creating a sustained seafaring culture and lasting sea power failed.[25] The English on the other hand enhanced their sea power and their merchant shipping capabilities and with these, the social status of mariners and merchants grew and their interests gained prominence.[26] The English nation emerged from the war with Spain committed to the idea that maritime endeavors would provide the surest path to prosperity abroad and security at home. The maritime community had succeeded in elevating its strategic objectives to the national level at the expense of traditional feudal and agrarian interests.

Moreover, when discussing the development over the ensuing decades of offensive naval power, maritime institutions, national fleet logistics infrastructure, global trade networks, modern financial devices, maritime technology, and navigation science, the Armada date is a convenient marker. From that time onward leadership was far more often located in the Protestant north rather than in the previous centers of innovation: the city states of the Italian peninsula or the kingdoms of Iberia.[27] Nowhere was this leadership more demonstrable than in the development of mathematical navigation and an embrace of a more sophisticated cosmology capable of

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[24] See footnote 14, [Glete, 161] for reference to standing navy. Glete, 162, describes the fruits of that building program – the Twelve Apostles – and their sinking of Grenville's *Revenge* in 1591, on one more failed English expedition to intercept the *flota* off the Azores.

[25] Glete, 164, notes that "Spain could not protect her sea lines of communication to Northern Europe, nor seriously disturb the lines of communications of her northern enemies. … We must suspect that the Spanish institutional framework for learning, adaptation and change was deficient."

Rodger, *Safeguard*, 293, notes that by "1603 the English Navy Royal was in most respects stronger and more capable than it had been at the outbreak of the war twenty years before, while Spanish sea power, after a precocious growth in the 1590s, was already decaying fast." He adds, 341, "when Phillip II died in September 1598, he owed one hundred million ducats, and interest payments were consuming two-thirds of his revenues."

[26] Rodger, *Safeguard*, 295, "The legacy of the privateering war was a transformation of the English merchant fleet, and of the London merchant class who owned so large a share of it. The same war which ruined Spanish shipping served to create the first English merchant fleet capable of long-distance trade, and to back that fleet with capital, skills and ambitions none of which had existed before."

[27] Glete, 147, when discussing the religious aspect of the Age, he notes that "in a maritime perspective it is obvious that the French, English and Dutch seamen who challenged the two Iberian powers around the world were also overwhelmingly Protestant. … The political power structure and its capacity for producing men with new ideas and competence for new tasks must have been important."

generating accurate global positioning. This in turn leads us back to our discussion on the emergence of heliocentric Copernicanism, its more sophisticated mathematics, and the proliferation of spherical trigonometry.

The acceptance of the new cosmology spread more rapidly in the Protestant north than it did in the Catholic south. However, this probably had far less to do with theology than it did with institutional realities and the urgency for acquiring more precise global accuracy at sea imposed upon the intellectual class by a maritime community more successful in imposing its priorities upon the state.[28] The early Protestant sects lacked the sophisticated institutional policing apparatus and the transnational orders, necessary to suppress heretical ideas, which were available to the Catholic Church. This is not to argue that Lutherans or Anglicans did not rigorously, and often violently, suppress dissent; but simply that they were not as efficient or institutionalized. As Kuhn notes, "Protestants nevertheless provided the first institutional opposition [to Copernicanism]."[29] This opposition existed without a manifest Catholic parallel for six decades. Martin Luther and his "principal lieutenant, Melanchthon,"[30] presiding over the intellectual hub of Protestant Germany at Wittenberg, both strongly opposed the Copernicus central heliocentric premise. However, as we have seen, this opposition was targeted at cosmology, just as the Catholic Index's redactions of *de Revolutionibus* (although not printed) would be after 1616. Kuhn contends that Catholics joined the fray against Copernicus late, after evidence had been accumulated in his favor. Ironically, they unleashed the Inquisition and banned heliocentric cosmology in 1616, but then were unable to retract their opposition.

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[28] Mokyr, 76, also challenges the "Protestant technology affinity' theme and asserts that "Moreover, the effects of the Reformation on the rate of technological progress were probably on the whole negative. That Protestantism itself was conducive to technological changes is doubtful. What matters to innovation is not only what one believes per se but to what extent society tolerates deviation and non-conformism (Goldstone, 1987)."
[29] Kuhn, 196.
[30] Ibid, 191.

Conversely, the Protestant north was able to reach a cosmographical accommodation much earlier.[31] This accommodation manifested itself in the colleges of mathematics and astronomy at the established universities and in new colleges founded in part to solve navigation problems.

Mathematical Navigation

By the early seventeenth century not only England, but also Holland and France had surpassed their Iberian rivals and launched into a period of intense northern competition that distinguished Taylor's Mathematical Navigation of the seventeenth and eighteenth centuries.[32] These nations set themselves to resolving problems of instrument observation, astronomical variation, compass deviation and inadequacies of flat projection (versus spherical projection) with improvements in astronomy (primarily with more accurate ephemerides) and in trigonometry and with the introduction of corrective charts, tables, and regiments. Mathematically trained sea officers, more precise instruments, and eventually, reliable chronometers produced precision navigation, but this journey was by no means easy and was characterized by sporadic achievements, erroneous detours, and long periods of stasis where the toll of navigation imprecision was regularly paid with blood and treasure. The seventeenth century witnessed a 'nautical arms race' – intense competition between the English and French (and often the Dutch) to push and exploit the scientific frontier of knowledge. They produced almanacs, royal societies of science, royal observatories, tide charts, and launched scientific expeditions. In short, political competition was driving math and science for a tangible benefit at

[31] Kuhn, 198-199.
[32] Rodger, *Safeguard*, 305, notes that "the Spanish war produced a large class of literate, even learned navigators, skilled in the arts which the Portuguese and Spaniards had pioneered. By the 1509s English scholars were themselves making important original advances in mathematics and navigation. In one generation they had passed from pupils of the Spaniards to teachers of the Dutch."

sea. Science became wedded to imperial ambition; navigation knowledge was indispensable for the project.

The ultimate triumph of English navigational science (and instrument and clock making) whereby its merchant fleet and navy could accurately ascertain their longitude at least once a day resulted from the convergence of two critical social developments. First, the nation as a whole embraced the sovereignty of the seas as its national mythology. Second, and equally as important, state and private interests straddling all classes dedicated both resources and intellectual capital to resolving navigation issues. In pursuing these goals, the English created a number of institutions whose impact on modernizing British society went well beyond the nautical.

From Mercator to Wright to Napier – Maritime Necessities

As the English nation embraced the maritime ethos at the end of the sixteenth century, it became painfully obvious to privy councilors, the heads of its few universities, and the increasingly educated gentry that England was not just a laggard vis-à-vis Iberia on the oceans, but compared to Western and Central Europe, it was also an intellectual backwater as well. To their credit, they met this deficiency with vigor and focused action. Within a generation, the English matched their great maritime leaps of the previous decades with resounding theoretical accomplishments and extraordinary innovations in practical mathematics. Nowhere was the success of their intellectualizing project more evident than in the field of mathematics. But unlike the disinterested scholars often portrayed in myth, the push to replicate a learned mathematical population and expand the frontier of mathematical science was in large part driven by the practical problems of global oceanic navigation so dear to both London's merchants and West Country pirates. Thomas Sonar, in the *Handbook of Geomathematics,* has observed that

> "Modern mathematics was needed badly in the art of navigation and public lectures were in fact already given in 1588 on behalf of the East India Company, the Muscovy Company, and the Virginia Company. Even before 1588 there were attempts by Richard Hakluyt to [fund] public lectures and none less than Francis Drake promised £20, but it needed the national shock of the attack of the Armada in 1588 to make such lectures come true."[33]

The English filled their education gap primarily with private lectures and endowed chairs at colleges dedicated to maritime needs.[34] Gresham College was founded in 1598 and would prove to be indispensable.[35] The two great established medieval universities at Cambridge and Oxford also became intricately involved in solving mariner's problems concerning mathematics, astronomy, and geography, or in producing mathematically literate men who used these talents for applied navigation problem analysis elsewhere. This was especially true within some of their constituent colleges; Trinity College and St. John's at the former, and Christ Church and New College at the latter.[36] Richard Hakluyt was a fellow of Christ Church and Thomas Hariot was a distinguished alumnus, and both were associated with Raleigh and his Virginia enterprise.

In order to establish global sea lines of communication, trade, and control; to defend outposts abroad; and to exert sea power against developed European naval and merchant fleets, aspiring maritime nations needed to improve their navigation skills. They needed to know

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[33] Sonar, Thomas, "Navigation on Sea: Topics in the History of Geomathematics," *Handbook of Geomathematics*, 48.

[34] Taylor, *Haven Finding*, 235, notes that in contrast the French appointed pilot-hydrographers, government instructors of navigation at their major ports, decentralizing the Spanish *Casa De Contratación* system, but maintaining government control.

[35] Johnson, Francis R., "Gresham College, Precursor to the Royal Society," *Journal of the History of Ideas,* **1:4** (1940), 422-423, notes that Sir Thomas Gresham, Elizabeth's financial advisor and the founder of the Royal Exchange, died in 1579 and bequeathed his mansion and the buildings and revenues of the Exchange to the City of London and the Company of Mercers to commence after the death of his wife, who died in December of 1596. From the revenues he endowed seven chairs (Law, Rhetoric, Divinity, Music, Physic, Geometry, and Astronomy) and provided the mansion for lodging and lectures. The Mercers obtained possession in 1597 and installed the Professors in 1598. Oxford did not follow with professorships in Astronomy and Geometry until 1619.

[36] Cormack, 59-105, expounds on the "Network of Geographers" that was developed within these universities.

precisely where they were, where they were going, and be able to avoid the obstacles deadly to sailors along the way. Accomplishing this would require tackling four large related problems.

Seventeenth century mariners and the institutions that supported them identified the need to produce more reliable charts conducive to both plotting one's course in open ocean, and that could accurately represented the distances, latitudes, and longitudes of coastal destinations and hazards. The errors introduced by compass variation, identified since the first Portuguese forays into the Atlantic, required accommodation.[37] Accurately gauging one's travel distance at sea had to be established and this required a better understanding of leeway and ocean currents. Lastly, and most pressing, was the mariner's chimera of accurately determining one's longitude afloat. All of these problems required more sophisticated astronomy and mathematics; new theories on hydrography, magnetism, optics, and more precise instruments than hitherto had existed anywhere on the planet. Great strides were made in the seventeenth century towards resolving the first three of these problems. Solving longitude would have to wait until the eighteenth century, and we will address it in Chapter 8.

However at the heart of all these endeavors and inquiries was mathematics. It was during this period, in the small northwestern extremity of the Eurasian land mass that the modern epistemology centered on mathematical analysis and precision quantification emerged. It did so not due to some theological or philosophical upheaval, but rather to address the practical exigencies of men on little wooden boats pushed to the far reaches of the globe by wind and current. And although great leaps in mathematics were being developed from France to Poland,

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[37] Taylor, *The Haven-Finding Art*, 172-173, notes that the Portuguese noted and tried to compensate for magnetic compass variation before Columbus. This problem was not overly significant in the closed circuit Mediterranean, but vexed Atlantic sailors leading to numerous fanciful intellectual paths and erroneous mechanisms for determining longitude at sea.

it was in late Tudor and Stuart England that a nation first consciously applied its talent and resources to learn, spread, and expand the mathematical canon for material benefits.

However the Elizabethan and Stuart English did far more than condescend to broadly disseminate state of the field geometry and trigonometry pre-calculated and encapsulated in tables to a hitherto ill regarded maritime class.[38] They also developed mathematical tools to make intricate theoretical concepts manageable at sea for an ever growing, and increasingly literate, nautical population. In expanding upon the Portuguese and Spanish programs of encasing astronomical data in preset tables, the English accomplished the task of encasing complex and time consuming mathematical procedures in practical tools which enabled mariners to quickly interpolate their own data at sea and to collect more accurate input data for the intellectuals theorizing from the safety of the metropolis. The most significant tool that emerged early in this century was the development of logarithms.

Logarithms, Gresham College, and Focused Intellectual Patronage

In 1614, the Scottish gentleman and mathematician John Napier published *Mirifici logarithmorum canonis descriptio*, in which he "provided tables based on a relation that would be nothing short of 'wonder-working' for practitioners."[39] He created his neologism from the Greek words *logos* (proportion or ratio), and *arithmos* (number). His success in creating a

[38] Clark, Kathleen M. and Clemency Montelle, "Logarithms: The Early History of a Familiar Function - Before Logarithms: The Computational Demands of the Late Sixteenth Century," Mathematical Association of America, http://www.maa.org/press/periodicals/convergence/logarithms-the-early-history-of-a-familiar-function-before-logarithms-the-computational-demands-of . "The late sixteenth century saw unprecedented development in many scientific fields; notably, observational astronomy, long-distance navigation, and geodesy science, or efforts to measure and represent the earth. These endeavors required much from mathematics. For the most part, their foundation was trigonometry, and trigonometric tables, identities, and related calculation were the subject of intensive enterprise."

[39] Ibid, "Logarithms: The Early History of a Familiar Function - John Napier Introduces Logarithms," Mathematical Association of America, http://www.maa.org/press/periodicals/convergence/logarithms-the-early-history-of-a-familiar-function-john-napier-introduces-logarithms . Translation: *A Description of the Wonderful Table of Logarithms.*

simple computational method for trigonometric functions capped centuries of efforts to simplify calculation and to derive proportions between geometric and arithmetic functions.[40] It also opened up research avenues for accomplishing new and varied mathematical simplifications.

Written in Latin for scholars across Europe, the work gained its early widespread popularity due to the efforts of an astronomer and navigation expert, Henry Briggs of Gresham College, and the mathematician Edward Wright, who was also recognized the monumental impact Napier's work could have when applied at sea.[41] Wright, who was revered by the English maritime community for producing the first Mercator projection charts, was no stranger to the problems faced by Stuart navigators. Waters notes that

> "Wright, like Briggs, had also perceived the importance of Napier's work. Moreover, with his strong navigational bent he had seen that, if the Latin text was put into English, it would prove to be 'of very great use for Mariners … a booke of more than ordinary worth, especially for Sea-men.'"[42]

Within a year, and with the financial support of the East India Company Wright undertook the translation, which was completed by Briggs after the former's death. No less a luminary than Kepler urged Napier to explain how he constructed logarithmic tables in his work.[43] Like Wright, Napier died before completing this task and it was left once again to Briggs to publish.[44] But where astronomers and academics wanted theory and algorithms, navigators wanted tables

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[40] Waters, 403, notes that these trigonometric logarithms were not "hyperbolic logarithms to base e." He adds, 406, that in an ironic sense Napier was indebted to two centuries of mathematicians who laboriously produced tables of the natural trigonometric functions which "his little book had rendered obsolete."

[41] Cormack, 82, observes that Briggs received his B.A. and M.A. from St. John's College, Cambridge, and was the Professor of Geometry at Gresham College (1596-1620) and later Professor of Astronomy at Oxford (1619-1630).

[42] Waters, 404.

[43] Ibid, 407.

[44] Ibid. He adds that in 1619 Briggs published *Mirifici Logarithmorum Canonis Constructio* describing Napier's method and also added tables for calculations in spherical trigonometry.

of common trigonometric functions for use at sea. Gresham College, Wright, Briggs, and the Welsh clergyman and mathematician Edmund Gunter brought this to fruition.[45]

However, whereas Briggs produced tables to satisfy the accuracy critical to academic mathematicians, Gunter chose to mechanize those tables for quick and generally accurate results.[46] He produced a precursor to the slide-rule that allowed mariners to quickly read the sine or tangent of an angle, and thereby input that data into their navigation or course calculations using only dividers.[47] He adapted the cross-staff for this purpose which was about two feet long. On one side of his scale he listed trigonometric and specific navigation functions (miles of longitude or sines of rhumbs). On the other he added a simple logarithmic scale. The aggregate effect of all these efforts and instrumentation was profound: widespread mathematical navigation was to quickly become the norm in both the Dutch and English maritime communities. And in the Protestant north, governments, trading conglomerates, and successful pirates were funding and encouraging the intellectual research and instrument making that was helping shape the emerging modern society as mathematical and reliant on a wide array of artifacts embedded with theory that few of their users even remotely understood. Former masters of specific crafts like navigation were becoming reliant upon a wider and higher breadth of society in order to exercise their craft. The embedding of technology with intricate scientific theory was enhancing proficiency and survival at sea, but also subordinating practitioners to a growing educated elite.

[45] Taylor, Haven Finding, 228, notes the integral role of Gresham College professors in addressing maritime dilemmas. "Henry Briggs, Gresham professor of geometry, had given considerable assistance to Edward Wright, and Edmund Gunter, the third professor of astronomy at Gresham College, gave definitive teaching on navigational problems …" worked nautical problems into his texts, and invented maritime instruments.

Cormack, 66, notes that Gunter received his B.A., B.Th., and MA from Christ Church and assumes that his geographical interests were in fact stimulated at Oxford.

[46] Waters, 416.

[47] Ibid, 419, "Gunter's Scale was the immediate ancestor of the slide-rule. Except that distances were measured by a pair of compasses [dividers] and not by another rule, it was a slide-rule. It performed all that a slide-rule does. Remove the sliding scale from a modern slide-rule and you have Gunter's logarithmic scale."

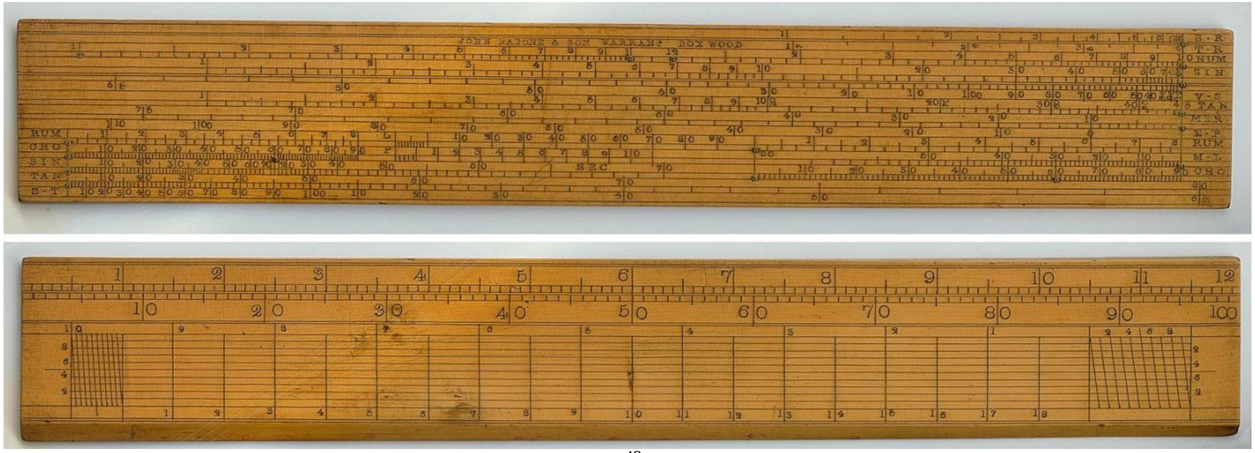


Figure 7.1. A Gunter Scale of the Nineteenth Century.[48] When coupled with dividers, this predecessor to the slide-rule allowed seventeenth century mariners to quickly 'read' trigonometric quantities essential to global navigation without laborious mathematical calculation or resorting to tables. The upper face of the scale lists standard trigonometric functions such as sine and tangent, as well as providing scales for calculating the latitude delineated distance of a minute of longitude. The rear side could have a logarithmic table or scales used for gauging chart distance.

This educated elite was of course itself subordinate to the rulers of the old order, even if these people were themselves modern state makers. As we have noted in Chapter 6, the powerful interests of Elizabethan England realized that their maritime ambitions could only be achieved by improving England's knowledge base. Once they had absorbed the Iberian nautical canon they were determined to expand its contents and husband the fruits of their inquiries. Some of the greatest minds of Elizabethan and early Stuart England were recruited for this effort. Like John Dee before them, many of these scholars took at least one overseas journey to better understand the practical needs of mariners and for the chance to discover exotica from the New World. Thomas Hariot, an astronomer, mathematician, linguist, and theoretician on refraction was employed by Sir Walter Raleigh on his Virginia ventures. Edward Wright sailed with the Earl of Cumberland to the Azores. Robert Hues went into South Seas with Thomas Cavendish, Abraham Kendall acted as skilled observer for Robert Dudley, Thomas Widdows accompanied

[48] "Gunter's Rule," Nzeldes.com, http://www.nzeldes.com/HOC/Gunter.htm.

Henry Hudson on his last voyage, and Thomas Hood designed instruments and charts, and lectured mariners in London.[49]

On his westward voyage to Virginia, Hariot [alternatively Harriot, Hariet, or Harriott] examined the mariner's instruments and attempted to resolve their complaints regarding differing latitude results between solar and stellar observations. Taylor notes that he ascribed this error to faulty North Star regiments and upon his return to England he set about resolving the problem at an observatory he set up upon the roof of one of Raleigh's London homes. Through his own observations and by comparison to those of Gemma Frisius, Hariot concluded that "owing to the precision of the equinoxes, the figure altered by about 24′ [minutes of degree] in a century." [50] He also confirmed the notion of Pedro Nunez and Thomas Digges that the true height of the pole star varied with the mariner's latitude, but unlike them, he addressed the problem by creating new pole star charts adjusted for every tenth of a degree of latitude. In fact these corrections were in a practical sense overdone or even moot, as with those regarding the dip of the horizon, due to the inaccuracies inherent in sixteenth century instruments. But his observations motivated instrument makers into seeking solutions for errors introduced by parallax and finer graduation of scales. He recommended avoiding solar glare by outlining several design's for a back-staff, requiring the observer to read shadow and horizon, rather than ascertaining solar height by staring directly at the sun while simultaneously fixing the horizon.[51] He also addressed compass variation by creating tables of solar declination by latitude which allowed for corrections for magnetic variation at sunrise or sunset. However, Taylor notes that all these innovations, while

[49] Taylor, *Late Tudor and Early Stuart Geography*, 68 and Taylor, *The Haven-Finding Art*, 215.
Cormack, 78, notes that Hood earned his B.A. and M.A. from Trinity College, Cambridge, and went on to lecture on navigation for London merchants and the East India Company.

[50] Taylor, *Haven-Finding*, 219, notes that he established it at Durham House in the Strand and probably used a twelve foot staff for his observations.

[51] Ibid, 219, asserts that the Elizabethan explorer John Davis constructed such an instrument. The 'Davis Quadrant' became the standard instrument for taking celestial observations for over a century and was only replaced by the widespread use of the sextant in the eighteenth century.

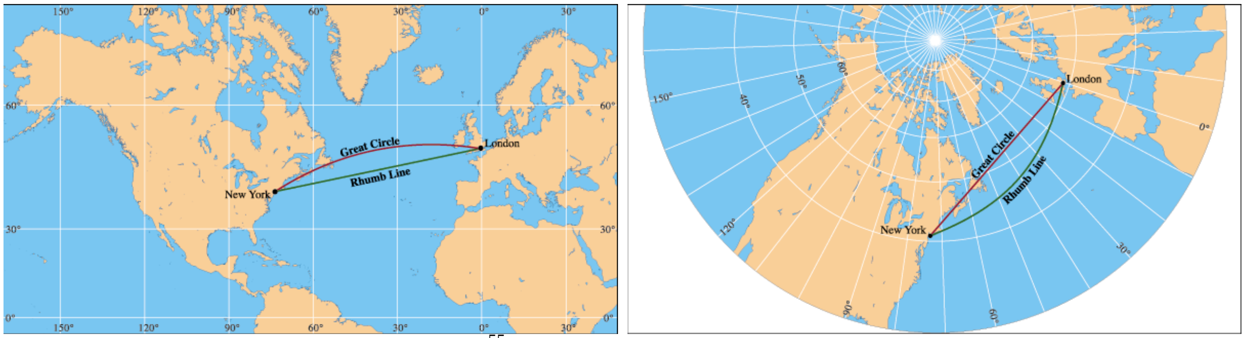
extant in Hariot's papers and used by Elizabethan sailors, were not published. These nautical secrets were the property of his employer, Sir Walter Raleigh, although both the Portuguese and French were able to both purloin and publish them.[52] While most of Hariot's innovations were helpful to practicing navigators, they addressed the problem of fixing one's present location at sea by latitude. However, both he and Edward Wright were also concerned with taking a Flemish innovation in nautical cartography and making it a practical tool for English seamen to both identify their location in regards to their destination without landmarks and to plot their course heading, laid out on paper which was currently impossible to do on a plain chart, since it could not accurately replicate a globe.

Gerardus Mercator presented his cylindrical world map projection in 1569. His innovation was to invert the convention of the plain chart where the distances between latitudes are correctly spaced and those between longitudes are distorted as then run in parallel away from the equator towards the poles. This distortion made it impossible to chart (or draw) an accurate course line on the chart, especially in the higher latitudes frequented by the English. Mercator's solution was to distort the spacing between latitude lines in the proportion to the spacing of parallels on a plain chart. Simply put, he unwrapped a globe and flattened it in such a way as to keep the notional lines essential to navigation true. As a result, the size of land masses increases closer to the poles.[53] But the significance of the distortion was for mariners. The projection

[52] Taylor, *Haven-Finding*, 220, notes that the Portuguese pilot Manuel de Figueiredo published the compass adjustment solar tables in his *Hydrografia* in 1608. This was translated into French by Nicholas Lebon and translated again by Jean Le Tellier and extended to 66 degrees of latitude in 1631. However, "No English tables appeared until 1664."

[53] Mark Monmonier's work *Rhumb Lines and Map Wars: A Social History of the Mercator Projection* is partially intended to debunk the revisionist assaults of German historian Arno Peters, who in the 1970s presented a world map that prioritizes actual area of land masses rather than Mercator's navigation priority with its resulting land distortions in higher latitudes. Monmonier corrects the record by clearly tracing the history of the projection and its intended use at sea to solve life threatening threats to navigation, and illustrates that it was not intended as some proto-imperialist plot to distort the relative size of southern land masses vis-à-vis those of Europe in order to belittle the station and importance of tropical countries. He concedes the projection could be used for political ends never

made it possible to plot a straight line course (along a rhumb line or loxodromes) of a constant compass bearing that would intersect the lines of meridian at the same angle throughout the entire course. [54]



Map 7.2. Rhumb Lines and Great Circles.[55] A single rhumb line (loxodrome) course from London to New York depicted upon Mercator and polar projections respectively. The rhumb line course had the considerable advantage of providing navigators with a single compass bearing and a consistent angle of meridian intersection for the entire course. The advantage of the great circle course is counterintuitive and requires a constant changing of compass heading, but is the shorter distance. In the case above, the rhumb line route of 3,110 nautical miles (nm) is 113 nm longer than this 2,996 nm great circle route, or 4% longer.

However, Taylor observes that the Mercator's innovation was directed at scholars and was not practical for seamen. It did not follow the conventions of sea charts of the day that mariners would recognize. All the legends were in Latin. He included coastline data based upon literary sources rather than from the observations and rutters of pilots.[56] As a result, his innovation was not quickly adapted. More significantly, Mercator did not provide a detailed

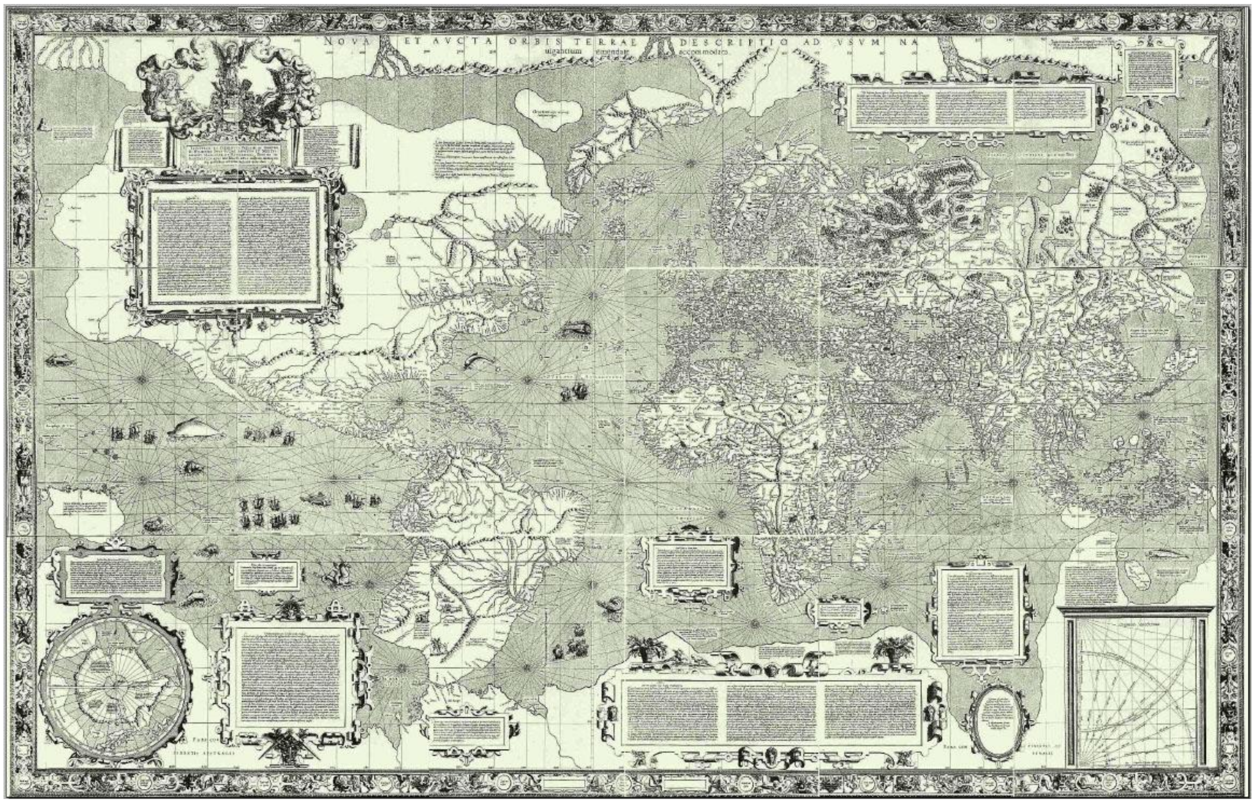
intended by its creator or the English mathematicians that adapted it for practical use. He also notes, ix-xi, the varied reasons the transverse Mercator projection survives past the Age of Sail due to its usefulness in "topographic maps, military grids, and electronic geographic databases, as well as the oblique Mercator projection, valuable in aeronautics, and the Space Oblique Mercator projection, used to add meridians and parallels to satellite imagery."

[54] Monmonier, Mark, *Rhumb Lines and Map Wars: A Social History of the Mercator Projection*, 6, "Although more than a century passed before Edmund Halley (1656 – 1742) recognized conformity as a mathematical property, Mercator's 1569 world map became the first conformal projection to portray meridians and parallels as straight lines." It was the projection's conformity that made nautical triangles possible.

[55] Franco, Karen, "Spherical Geometry: Exploring the World with Math," Math.ubc.ca, http://www.math.ubc.ca/~cass/courses/m308-02b/projects/franco/index.htm.

[56] Taylor, *Haven Finding*, 222, "Mercator's production was, it must be admitted, essentially a scholar's map. It was not drawn according to the conventions of a sea-chart, and it included conjectural coastlines based on literary sources. The legends were in Latin and the principle of the new projection was not explained nor its method of construction indicated."

mathematical procedure for widening the parallels as the map moved northward.[57] Once more, as noted above in regards to Hariot's innovations, instrument precision and magnetic variation helped stymie early adoption. But his work did inspire imitation and innovation from a generation of English mathematicians and astronomers such as Hariot, Wright, and Henry Bond.



Map 7.3. A Scholar's Chart: Mercator 1569 world map (*Nova et Aucta Orbis Terrae Descriptio ad Usum Navigantium Emendate Accommodata*) showing latitudes 66°S to 80°N.[58] The title, *New and More Complete Representation of the Terrestrial Globe Properly Adapted for use in Navigation*, presents the work to mariners.[59] However, it was not practical for seamen. It did not follow the conventions of sea charts of the day, all the legends were in Latin, and he included coastline data based upon literary sources rather than from the observations and rutters of pilots. The description of nautical triangle (lower left) would have been incomprehensible to sixteenth century mariners.[60] Once again, note the conventional wisdom of an attached South American and Antarctic link to an enormous southern continent separated only by Magellan's straight and a North America extending much further west than actual. Also present are the illusory Northwest and Northeast Passages to Cathay.

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[57] Monmonier, 8, notes that Mercator's method was itself a mystery; speculation varies as to whether he used mathematical approximations or traced spiraling loxodromes on globes and graphically produced his projection.
[58] Image from "Mercator 1569 World Map," Wikimedia.org, https://en.wikipedia.org/wiki/Mercator_1569_world_map#/media/File:Mercator_1569.png.
[59] Monmonier, 4.
[60] Taylor, *Haven Finding*, 222.

In the 1590s both Hariot and Wright attempted to replicate Mercator's projection by creating a table of meridional parts and utilizing the fruits of decades of trigonometric expansion.[61] Wright was the first to produce a table in *Certaine Errors in Navigation* (1599), of meridional parts which could be used by chartmakers to construct a Mercator projection. Contemporaneously Harriot improved upon Wright's approach of constructing a meridional table by "merely adding up secants."[62] He used a logarithmic tangent formula which was more precise.[63] His discovery was not published, and was eclipsed by Henry Bond who crafted a formula in 1645 after noticing a correlation between Wright's tables and a table of the logarithms of tangents published by Edmund Gunter in 1620.[64] This formula enabled chartmakers to create projections without pre-calculated meridional tables; however, one would still need logarithmic tangent tables. Fortunately for seventeenth English seamen, the nation's best mathematical minds were producing such tables and producing logarithmic charts to solve an ever increasing range of mathematical problems. As Taylor has noted,

> "On the Wright-Mercator projection the sailor could draw for the first time a 'nautical triangle' which showed latitude and longitude, direction and course correctly. … The introduction [by Thomas Hariot in 1600] of the 'true' chart, which any chart-maker could now draw with the help of [Edward] Wright's tables, was the most important advance in

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[61] Monmonier, xi.

Taylor, *Haven Finding*, 223, elaborates that these tables of meridional parts were measures of "spacing of the lines of latitude." She notes that both he and Hariot built their tables "by a continuous addition of 1′ [minute] intervals, Hariot using the trigonometric tables published by Christopher Clavius in 1586, and Wright those of G.J. Rheticus, published in 1596, at least for the final version of his figures."

Cormack, 103, notes Wright was preceded in his effort by William Barlow who in 1597 published *The Navigator's Supply*, wherein he "presented a graphical method for creating a Mercator projection … [and] encouraged navigators to draw their own charts." However, he did not provide clear instructions or any useful mathematical insights, so that his admonition to create Mercator charts was not really possible using his work.

[62] Monmonier, 72.

[63] Taylor, *Haven Finding*, 223, notes that Hariot's unpublished draft, *The Doctrine of Nauticall Triangles Compendious*, approximated the modern formula $M = K \log \tan (45^{o} + \phi/2)$, prior to the invention of either logarithms or calculus.

[64] Monmonier, 72-73, notes that after rearranging Gunter's table and assigning latitude as ϕ, the radius of the globe as R (the scale of the projection), and y as the distance of a projection parallel from the equator, then: $y = R \ln \tan (45^{o} + \phi/2)$. Bond, 50 years after Wright had derived a compact logarithmic equation (xii) for meridional parts.

navigational technique since the Portuguese astronomers had first taught the use of solar declination. And it coincided with the introduction of trigonometry into general use."[65]

The dawn of mathematical navigation was enabled by advances in mathematics driven by direct navigational needs resulting from precision errors and spherical distortion of distance between lines of longitude at higher latitudes. That these problems were addressed by high latitude nations is not surprising. What is surprising is the leading role played by the heretofore mathematically stunted English nation.[66]

Map 7.4. Wright-Molyneux Map (1599).[67] This Mercator projection included in Hakluyt's 2nd volume of Hakluyt's *Voyages and Discoveries: The Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation*, has been credited to Wright and was possibly detailed off a globe made by Emery Molyneux in 1592.[68] Like Mercator's work of 1569, it retains the portolan sailing rhumb lines centered on various compass roses. It represents state of the art English navigation knowledge at the dawn of the seventeenth century. Wright also

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[65] Taylor, *Haven Finding*, 224-225.
[66] Cormack, 105, concurs that Wright's projection was the first truly mathematically produced Mercator projection, and "that it placed English mathematicians, for a time, in the vanguard of European mathematical geography."
[67] Image from https://commons.wikimedia.org/wiki/File:WrightMolyneux-ChartoftheWorld-c1599-large.jpg.
[68] Taylor, *Haven Finding*, 223-224, notes that Hariot could in fact be the author as Wright is somewhat vague about the freshness of his 1610 world map.

incorporated geographical data from Dutch, Portuguese, and Spanish charts.[69] Note that Antarctica is missing along with Drake's Passage. Also incomplete is the North American northwest and most of the Pacific Ocean. It was however, more accurate and useful than Mercator's original projection, and with the help of Wright's tables; replicable.

The Problem of Compass Variation

We touched on the physical phenomenon of magnetic variation, its variable impact in different parts of the world upon compasses, and the problem this caused Early Modern navigators briefly at the end of Chapter 5 in our discussion upon William Bourne's *Regiment for the Sea* and in more detail in Chapter 6 when examining Dr. William Gilbert's studies on magnetism and the possible assistance his theories and instruments could provide to mariners. We also reviewed the reciprocal influence that existed between Gilbert and practical navigation practitioners and theorists such as William Borough. In his *A Discovrs of the Variation of the Cumpas* of 1581, he admonished sailors to collect data on variation regularly throughout their travels and "blamed variation with wreaking havoc with chart construction."[70] As an early and enthusiastic proponent of Mercator's projection, Borough grasped the advantages that accurately plotting and measuring one's course could bring. Accurate readings required adjusting for compass variation.

In order to control the misleading headings provided in sixteenth century vessels, Northern European mariners constructed compasses with preset deviations roughly approximate to the measured variation within their local sailing area (see Chapter 6 and Gilbert's regional recommendations). N.H. Heathcote de Vaudrey notes that allowances for variation were in wide use in the sixteenth century on Flemish or Dutch vessels. Italian compasses did not account for variation, most probably because their local geography did not present this problem for technical resolution. His conclusion is that the Flemish mariners and instrument makers deserve

[69] Monmonier, 70-71.
[70] Cormack, 95, references preface to work.

the credit, derived out of a need to reconcile astronomical findings with deviant compass readings, for adapting their instruments to account for magnetic variation.[71] Regardless of precedence, seventeenth century mariners needed a better solution than preset deviant compasses. They travelled widely and through multiple zones of variation and their astronomical tables and charting improvements required more granular adjustments than fractional pieces of an 11-¼ degree compass point. As more data came home aboard ships, scholars and mathematical sailors were also beginning to understand that magnetic declination or variation was a temporal phenomenon as well.

The accumulation of data for cosmopolitan academics reinforced the symbiotic relation that existed between early modern sciences and oceanic navigation. In order to provide mariners with useful charts scholars needed data and this data helped shape, confirm, and reject theory. The need for more precise and detailed readings also inspired the first truly scientific voyages of the modern era, but we will address this in the next chapter. At this point, mariners were collecting enough readings to understand the importance of confirming their daily compass variations, and starting to accurately record their voyage's progress on charts and in their sailing journals. However, another major obstacle impeding seventeenth century mariners concerned ascertaining not just their vessel's true heading, but its daily progress across an inaccurately measured planet.

Leeway, D'ed Reckoning, and Logs

In creating a nautical chart useful for charting courses accurately, deciding upon a projection method and making its production replicable was not quite enough. A corresponding problem concerned describing the length of a degree of meridian. For a chart to be useful for

[71] Heathcote, 89-93.

plotting courses, distances and scales at different latitudes had to be derived. This derivation could not be accomplished without accurate physical measurements of the planet. Estimates of the circumference of the equator and breadth of the continents go back to the earliest Greek astronomers. However, it was in Early Modern Northwestern Europe, where the exigencies of maritime trade and naval power, encouraged scholars and nations to systematically tackle this problem. By the time Gunter was Professor of Astronomy at Gresham College, he challenged the English convention of the day that the measure of a degree was sixty miles of 5,000 feet. His subsequent elaboration and the conservative desire of mariners to keep a minute of degree equal to a mile heralded the creation of the distinct nautical mile.[72] Richard Norward, who, like William Bourne had been a sailor in his early life and had taught himself mathematics, expanded upon Gunter's work. In his 1637 navigation textbook, *The Seaman's Practice*, Richard Norwood recommended a 'sea mile' of 6,000 feet and proposed changing the knot intervals on the log line from seven fathoms to fifty feet.[73] Norwood's remarkably accurate calculation of 69 land miles to the degree of latitude led him to recommend usage of a sea mile approximately 15% larger than the land mile.

Mariners of all places and times have attempted to estimate their distance travelled, but throughout history most sailors, by staying near coasts, could use recognizable landmarks, bird sightings, or depth soundings to assist them. Open ocean sailing prompted the need for new

[72]Taylor, *Haven Finding*, 230, Gunter determined that there were 352,000 feet to a degree [rather than 300,000]. However, Taylor notes that "the relationship of a mile to a minute of arc was too convenient a one to be sacrificed, and the nautical mile parted company with the geographical mile."

The United States Geological Survey notes that although degrees of latitude vary slightly due to the irregular shape of the earth, "At 38 degrees North latitude, one degree of latitude equals approximately 364,000 ft. (69 miles), one minute equals 6068 ft. (1.15 miles)," https://www2.usgs.gov/faq/categories/9794/3022.

A nautical mile is now calibrated as 1.1508 miles, or 6,076 feet. One nautical mile (nm) represents one minute of a degree of latitude, sixty nm equals one degree of latitude.

[73] Taylor, *Haven Finding*, 230, Norwood, a land surveyor by trade, based his recommendation on his surprisingly accurate measurement of the distance between London and York. He fixed the measure of a degree at a little over sixty-nine land miles.

methods of guessing at one's distance travelled. This process was referred to as Dead Reckoning, from deduced, or as abbreviated 'D'ed' Reckoning.[74] Simply put, it was a system of estimating a ship's position by estimating the distance travelled from a known point by an amalgam of guesses about ship speed, current strength, drift, and leeward wind pressure. English sailors, unlike their Iberian contemporaries attempted to estimate their distance travelled and speed by regularly throwing a log tethered to a line knotted at regular intervals and comparing the number of knots played out to a time regulated by a small sand glass. They recorded their readings in their sailing journal or 'log book' and marked (or pricked with a pin) this distance on their sailing charts. By making the theoretical measure of a degree of meridian more accurate and by improving knot and log speed estimation more reliable, English academics were able to provide their national sailors with more precise processes for gauging distance traveled, for accurately recording it on a chart, for creating charts that more accurately displayed global distances and bearings at sea, and thereby providing mariners with means to avoid known dangers or to make more accurate landfalls. Across the Channel, in the next century, France under the guidance of Louis XIV's Minister of Marine, Jean-Fréderic Phélypeaux, comte de Maurepas, expended larger resources towards resolving the precise measure of the degree, but for the task of making the new chart reliable, Gunter and Norwood's approximations were good enough for seventeenth century sailing, especially when one contemplates the state of instrument precision.

As the maritime project grew and the types of participants involved contributed their talents, numerous serendipitous confluences spurred overall technological progress. Decades of continental astronomical and mathematical progress produced navigation tables that enabled mariners to flood the Atlantic metropoles with data, sometimes conflicting with and at others

[74] Blake, John, *The Sea Chart: The Illustrated History of Nautical Maps and Navigational Charts*, 15.

corroborating the received wisdom of the moment, shaking medieval epistemology. Nautical demands drove the frontiers of both sciences and in turn, their theoretical advances pushed the ships further and more reliably than ever before. Another dramatic technological leap with impacts far beyond just astronomy was the development of the telescope and the related science of optics. But it was astronomy where the device had its first great impact as we discussed in Chapter 4, especially by dramatically improving the observations of Tycho Brahe and his intellectual descendants. Eventually the new science of optics and the skills of instrument makers were blended to create navigational instruments which enabled mariners to take advantage of the properties of Mercator charts, better astronomical tables, and growing hydrographic databases. We will address these instruments in the next chapter, but first let us turn to ships. Matching the dramatic improvements in navigation technology, theory, and practice in the seventeenth century was a dramatic improvement in both the construction, durability, and sailing capabilities of ships, but also in the land based infrastructure to build, arm, and maintain them in ever increasing quantity.

From Carrack to Ship of the Line

As noted in Chapter 3, the medieval cog of northern waters both inspired some of the innovative Mediterranean and Iberian ship design of the fourteenth century and when modified with the improvements designed for the caravels by these same southern shipwrights (carvel construction and mixed sailing rigs), evolved into the *cocha* or carrack.[75] These southern carracks sailed north and displaced the cog as the ship of choice for both trade and for conversion into fighting vessels in the fifteenth century. Rodger notes that English piracy may

[75] Rodger, *Safeguard*, 63, notes that "the cog developed in the twelfth and thirteenth century into the dominant cargo vessel of northern waters." It was shell built and featured a reinforced flat bottom, but despite its ability to safely ground at low tide, "the rise of the cog goes in parallel with the building of quays [marine loading platforms, usually stone] at all the major ports of northern Europe."

even have provided Henry V with templates, when in 1409; they captured the Genoese *Santa Maria & Santa Brigida*.[76] By 1420, the single masted flat bottomed tub-like cog was sharing the Channel with the 1,400 ton (burthen) *Grace Dieu*, as the northern kings initiated one of the world's first naval arms races which would culminate two centuries later in the ship of the line paradigm that would itself only be displaced by the advent of steam and steel.

Angus Konstam, in *Sovereigns of the Sea*, describes the technical evolution of sail driven gunnery platforms throughout the Renaissance, and the culmination of the quest to build the perfect battleship that was realized in the creation of this eponymous English warship that emerged at the dawn of the early modern period. This immense ship was a product of centuries of Medieval and Renaissance nautical experience, but was also a child of the nascent Scientific Revolution.[77] Konstam contends that when Charles I launched the *Sovereign of the Seas* in 1637, it was in effect the first ship of the line – the ships that were the mainstay of European navies for the next two centuries, the culmination and exemplars of the Age of Sail.[78]

However, this evolution was one where technological advances, to include disastrous detours, outstripped the tactical and technical knowledge of the shipwrights, sailors, admirals, and princes who conceived these behemoth floating arsenals. The determinative effect of firepower was generally accepted only long after the technology was mounted on ships. Eons of naval battle featuring preliminary maneuver and salvos of ranged volleys (whether by missile troops or primitive guns) was inevitably followed by a clash of ships and close action melee. Despite advances in foundry technology, gun mounting, and ballistic improvements, it took

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[76] Rodger, *Safeguard*, 68.
[77] Konstam, *Sovereigns*, 86, notes that James IV of Scotland "had a fascination for science, invention, military technologies, and anything that smacked of progress. He established a gun foundry in Edinburgh Castle, created a college of surgeons, founded two universities, and even encouraged the establishment of Scotland's first printing press." His southern adversary, Henry VIII, despite his conservative religious beliefs, was also a product of the humanist education of Thomas Moore and shared James' fascination with new technology and likewise imported Italian foundry experts.
[78] Ibid, 7, 301.

centuries for Europe's naval commanders to see heavy gunnery as anything other than an auxiliary weapon that was best used to cause chaos prior to the bloody clash of infantry forces at sea.[79] Sea battles were hitherto always fought close to land and often in sea conditions calm enough to provide stable fighting platforms for the opposing ship mounted armies.

The naval tactics of the period were focused upon bringing one's force close enough to the enemy to engage, or in avoiding such a conflict if outnumbered. Rodgers summarizes the contemporary Philippe de Clèves's tactical manuals. His four-part instructions consisted of first getting to windward of the enemy, then running down onto the enemy firing small arms, leading to coming alongside the enemy and discharging one's heavy bombards, and finally, boarding the enemy in the smoke and concussive confusion wrought by the bombard assault.[80] The seaman's job was bringing the enemy to bear and creating a stable battlefield on water for his feudal overlord to fight a conventional land battle upon. Cannon would change this paradigm, but only after steady technological improvement, and as we have seen in our Armada example, only after monumental social factors were overcome by the existential challenges delivered by technological pioneers who by inspiration or necessity, challenged the existing order. Ironically, it was aboard the ancient technological weapon of the galley that the elevation of cannon from auxiliary weapon to main armament first began.

Introduction in the Mediterranean of galley bow mounted armament with ship-killing cannon which could be aimed directly by steering the galley countered the advantages in missile and boarding tactics which the high-walled more maneuverable mixed rigged sailing carracks

[79] Rodger, *Safeguard*, 163, 208, notes that ship killing guns first appear on Mediterranean galleys, mounted in the bows, in the 1470s. This technological system directed at ship killing, rather than capture by boarding, was not emulated on sailing vessels in the northern Atlantic for at least 50 years.

[80] Ibid, 205, 622, derived from tactical experience from the turn of the fifteenth and sixteenth centuries, Philippe de Clèves, seigneur de Ravestein, published *Instruction de toutes manieres de guerroyer (…) sur mer* [Instruction in all Ways of War on the Sea], published in 1558, but probably written circa 1505, "was an influential treatise dealing with naval tactics among other things … and reflects late 15th-century practice."

had previously enjoyed. Pioneered by the Venetians, ship-killing cannon changed naval warfare in the Mediterranean. By the Fourth Genoese-Venetian War, or the War of Chioggia, all Mediterranean galley fleets had added artillery to their bows.[81] Rodger notes that as wrought iron breach loaders were being replaced with bronze muzzle loaders by the Italians, the gun mounted galley became even more formidable.

> "The Venetians, with the best guns and gunners in the world, were prepared to open fire at up to five hundred yards. Muzzle-loaders with heavy charges led galleys to adopt sliding carriages in order to absorb the shock of the recoil without shaking a flimsy hull to pieces. Later the single heavy gun came to be flanked by two, and eventually four lighter guns. … The result was that carracks rapidly disappeared from the war fleets of the Mediterranean."[82]

However, the impact of this tactical revolution did not largely impact naval warfare in the North Atlantic for over a century. It would take the involvement of nations with both a Mediterranean and Atlantic presence for this technological and tactical transfer to take place. These powers, the French, the Spanish, and the Genoese, brought their ship-killing galley fleets north despite the treacherous seas of the North Atlantic and the Bay of Biscay.

Konstam contends that the watershed event occurred early in the reign of Henry VIII. A French Mediterranean galley squadron using large bow guns devastated two becalmed English fleets. "The two battles fought off Pointe de St. Mathieu on August 10, 1512, and April 23, 1513, marked turning points in naval warfare."[83] Two schools developed; both accepting the importance of naval artillery. One saw artillery as critical prelude to the decisive boarding action, while the other glimpsed the potential of long-ranged gunnery as determinative.

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[81] Konstam, *Sovereigns*, 126, notes this conflict fought from 1378-1381 featured ubiquitous galley cannon.
Crowley, *City of Fortune*, 199, notes the introduction of early cannon (bombards for sieges) in late 14th century.
[82] Rodger, *Safeguard*, 208.
[83] Konstam, *Sovereigns*, 57.

The first nations to realize the 'sea change' heralded by effective ship-killing gunnery married to advanced sailing technology would usher in the new age of fighting sail. Up-gunning larger and larger ships and balancing the inherent instability wrought by size, weight, and timber rending broadsides with innovations in sailing rigs and ship design is the central theme of Konstam's work. Even at Lepanto in 1571, sailing ships were too unpredictable and hard to handle to make them effective warships. It was first in Atlantic Iberia and later in Northern Europe that dramatic improvements in sail configuration and hull design made sailing ships the ideal gun platforms of the next age. But even within the context of this larger ascendancy of sail over oars, there was an internal balancing act between ship handling (maneuverability and speed) and firepower, which despite the myths of the Spanish Armada, saw the latter rise triumphant.

The confluence of advances in both ordnance development and production, and in sailing technology (from hull design to the composition of sailing rigs) was fast paced and unpredictable. Ordinance advances on the ancient Mediterranean galley technology in northern waters threatened the new supremacy of maneuverable mixed rig sailing vessels. This threat was met with more alterations in hull design and ordnance placement. In order for sails to triumph over oars, the tactical advantages of bow mounted offensive galley technology would need to be adapted to sailing ships. The first break-through in this response was the galleon.

Although its origins are somewhat obscure the galleon was most likely a hybrid creation of the Spanish with Venetian influences, although Portuguese claims of paternity are not specious.[84] The first galleons were small and combined both sails and oars, but these ships

[84] Konstam, Angus, *Spanish Galleon, 1530-1690*, argues that the first galleon may have been "built in 1517 to fight the Barbary pirates in the Mediterranean." It "combined oars and sails like the Venetian galleon of the late 15th century. The Portuguese used similar small vessels they called galleons in the Indian Ocean during the 1520s."

Guilmartin, 158, notes that the Portuguese used galleons with oars to patrol the Indian Ocean in the 1510s.

rapidly grew and lost their oars as the ship-type matured by the middle of the sixteenth century.[85] However, the more important innovation that they took from the galley concerned the placement of armament. The galleons primary distinction over the carracks of the period was their low narrow sleek hull and long low beak-like bow mounted with heavy ordnance.[86] Where the carracks of the day were high walled with heavy castle structures fore and aft, and designed for infantry clashes, the first galleons were designed to fire on the attack while maneuvering toward an enemy like the galley.[87] Whether by firing directly ahead or yawing slightly to allow the side-mounted forward guns to fire, the galley did not rely on a defensive broadside prior to engagement or its stern chasers in retreat. Ironically, even though the Spanish developed and spread the ship-type throughout northern Europe, they were not the ones to fully exploit the offensive capability of the ship. They continued to rely on boarding and infantry clashes in their naval doctrine.[88] Perhaps constrained by a class system that elevated the aristocratic infantry commander over the mariner, or for reasons beyond the scope of this work, suffice to say that

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[85] Glete, 26, notes that "from the late fifteenth century on there were also smaller types of warship which attempted to combine some of the characteristics of the galley with those of the sailing ship. Several of these were called galleons or galleasses, … originally … interchangeable. Some of these vessels were oar-powered hybrids between galleys and full-rigged ships (this type gradually became known as galleasses), while others were low-hulled sailing ships (later often known as galleons).

[86] Rodger, *Safeguard*, 209, contends "that what they were trying to do was not to develop the broadside armament [with the innovation of the continuous gun deck], but to supersede it; to design a sailing ship with a powerful ahead-firing armament which could beat the galley at her own game."

Glete, 26, notes that galleons pushed as many guns forward as possible "to combine offensive tactical movements with effective gunfire." However he caveats that the great carracks of the day were adjusting gun placement in a similar fashion. These guns would by the necessity of the hull configuration be placed high above the waterline on the carracks, were the galleon's forward armament would be closer to the waterline and more deadly to enemy ships in the same fashion galley armament was.

Konstam, *Sovereigns*, 175, notes that early galleons were modeled off of the Venetian *galleoni* (oars and sail hybrid), 176, that they featured a low forecastle and mixed sailing rig, and that both Atlantic and Mediterranean antecedents combined "the speed and maneuverability of the caravel with the cargo capacity of the nao and carrack." He adds 177, that they may have been designed for the *flota* after a French corsair raid on returning treasure caravels in 1523, and that, 181, "During the second half of the sixteenth century galleons kept growing."

[87] Guilmartin, 158-159, "The galleon was designed to carry its heaviest ordnance to fire forwards. Like the cannon-armed galley, the galleon's underwater lines provided extra buoyancy at the bow to support ordnance, ideally two heavy bow-chasers mounted under the forecastle on either side of the beak and two smaller chasers in the forecastle itself."

[88] Konstam, *Spanish Galleon*, 36, notes that "throughout the age of the galleon, the Spanish never realized the full potential of their naval artillery." Cannon as assault prep weapon only gave way to practicing stand-off artillery duels after the 1588 Armada campaign.

although the galleon was used effectively to counter the threat of the galley, the Spaniards of the sixteenth century would not be the ones to pioneer a new naval doctrine based upon ship-killing long-range artillery. At the spectacular Battle of Punta Delgada in 1582, Alvaro de Bazan, the first Marques de Santa Cruz, Spain's greatest admiral, defeated the larger French fleet guarding the Azores with a combined fleet of the most modern Spanish and captured Portuguese galleons afloat.[89] Despite being outnumbered, he fought the larger French carracks primarily with his tercios, eschewing long-range hit and run cannon fire aimed at ship-killing for a traditional boarding action. Technology far from being determinative played a distinctly subordinate role in sixteenth century Spain's social milieu.

The galleon's full sailing rig of square sails, lateens, and topsails, and her sleek hull design made her very seaworthy and maneuverable. She was easily capable of transatlantic sailing, but her relatively narrow hull and heavy complement of ordnance, made her more suited to piratical cruising or defense in home waters. She simply did not have the cargo capacity for extended sea voyages or long tours on station off an enemy coast far from supply bases.[90] Under the guidance of Queen Elizabeth's Treasurer of the Navy John Hawkins, the English developed a more pronounced version of the galleon emphasizing these features.[91] The English 'Race-built Galleon' was a variant of the galleon that emerged in the 1570s. It differed from its Spanish cousin in that its designers reworked its hull form to add speed and armament carrying capacity. Konstam notes that "these vessels were lower, having much less superstructure, with the

[89] Konstam, *Sovereigns*, 171-173, Phillip II inherits/invades Portugal in 1580 capturing 11 Portuguese galleons. Santa Cruz uses these ships as the nucleus of his smaller fleet that defeats the larger French fleet of carracks protecting Azores and the Portuguese government in exile in 1582.

[90] Guilmartin, 161, Spanish galleons designed to protect the transatlantic *flota*, by necessity carried far less ordnance than their English adversaries built for raiding.

[91] Ibid, 160, notes that the first race galleon built in 1573, the *Dreadnought*, carried guns weighing 4.5% of displacement compared to earlier galleons mounting 3%. The race galleon was carrying 50% more gunnery than its predecessors. By the time of the Armada, the gunnery weight was reaching 8-11% of displacement.

towering galleon stern-castle replaced with a gentle sloping quarterdeck."[92] Matthew Baker built the 500-ton *Revenge* in 1577. It was the first ship of this class and Drake's flagship during the Battle of the Gravelines, but it was quickly emulated under Hawkins's management in both the construction of new ships and the refitting of older ones. It was this innovative English derivative of the Spanish galleon, built to emphasize maneuverability and gun capacity, which would become the template for future warship development. However in this design we can observe an evolving conflict between designing for gunnery versus enhancing maneuver. In England, the former would gain preeminence in the decades ahead.

Figure 7.2. A Sixteenth Century Spanish Galleon.[93] This modern replica, *El Galeón*, is 170 feet long and is emblematic of the fully matured galleon ship-type. Note the mixed-rig sails with square sails on the main and fore

[92] Konstam, Angus, *Elizabethan Sea Dogs, 1560-1605*, 54, adds that they had a larger hull length to beam (width) ratio and a sail plan designed to carry more canvas area.

Herman, 187, notes that the evolving ships of the line increased the length to beam ratio from 2:1 to 3:1 over their Tudor predecessors. Speed was enhanced by adding a third tier of sails above the topsails (compare the sixteenth century galleon and the *Revenge* below) called 'top gallants'. Maneuverability was enhanced by getting rid of the bonaventure mizzen and adding a topsail above the bowsprit (an extra lateen sail forward).

[93] "El Galeon," Sailonboard.com, https://www.sailonboard.com/vessel/el-galeon/.

masts, with a lateen sail on the mizzen mast. It has a continuous gun deck close to the waterline and features the new closeable gun-ports of the era. The beak-like prow does not have the forward fighting castle of the medieval carrack, but rather emulates the galley's forward fighting armament of bow-mounted guns. The ship is a compilation of hybrids: the hull form has the front of a galley and the rear fighting castle of the carrack; it is a well-armed warship, but also designed to haul the precious specie cargo of the Spanish *flota*. The most versatile ship of the sixteenth century, this ship was copied by most of the North Atlantic powers and in their hands eventually evolved into the ship-of-the-line.

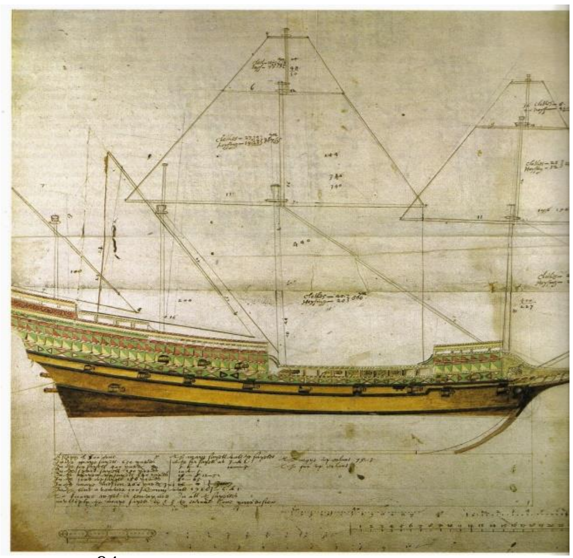
[94]

Figure 7.3. Matthew Baker's *Revenge*, 1577. The first Race-built Galleon became the proto-type for Hawkins's Elizabethan ship building program. Built in the Royal Dockyard, Deptford, to a design by Matthew Baker and launched in 1577, she had a length of keel of 110 feet and a beam of 34 feet. *Revenge* carried 43 assorted guns and a crew of 150 sailors, 24 gunners, and 76 soldiers. She was the flagship of Sir Frances Drake during the raid on Cadiz in 1587 and at the Gravelines in 1588. In 1591, Sir Richard Grenville lost *Revenge* to the Spanish fleet off the Azores; a fight that cost him and a good deal of his crew their lives and posthumous immortality in Lord Alfred Tennyson's "The Revenge: A Ballad of the Fleet." This plan was presented in Baker's *Fragments of Ancient English Shipwrightry* (1586). Note her low sleek hull, smaller stern-castle, and extensive sail plan in comparison to her Spanish Galleon predecessor presented above.

With the benefit of hindsight we can marvel at the slow acceptance of offensive naval tactics built around long-range gunnery, but this is unfair. The actors of the time were dealing with evolving technology that was far from mature. The large guns of the day were extremely expensive, often unreliable, hard to load, and created long before our age of standardized chemical mixtures and interchangeable parts. Guns often misfired or exploded, powder came in variable qualities that made accurately gauging projectile distance difficult, bore dimensions and the size of shot varied greatly creating targeting issues. Based upon the state of the technology at hand, a single discharge at close range, followed by boarding was not an unreasonable solution. It worked, but it was not innovative or appreciative of technological advances in gunnery, gun mounting, and ship construction on the near horizon. The galleon ship-type was an innovative

[94] The image of *Revenge* from Baker's *Fragments of Ancient English Shipwrightry* (1586), from "Revenge 1577," Horseandmusket2.blogspot.com, http://horseandmusket2.blogspot.com/2015/01/revenge-1577.html.

response to the forward attacking threat posed by the galleon. The galleon's sister, the large hybrid sailing ship with oars, the galleasses, was an innovative response to the lack of maneuverability still extant in sixteenth century ship rigging technology. These ships proved decisive at Lepanto and were included in Henry VIII's ship building program of the mid-1540s.[95] But both these ship types were developed to address technical problems of sailing ships vis-a-vie galleys in a medieval naval battle. The future command of the oceans would only come when northern nations exploited the full potential of sailing technology and naval gunnery and jettisoned the naval infantry battle paradigm.

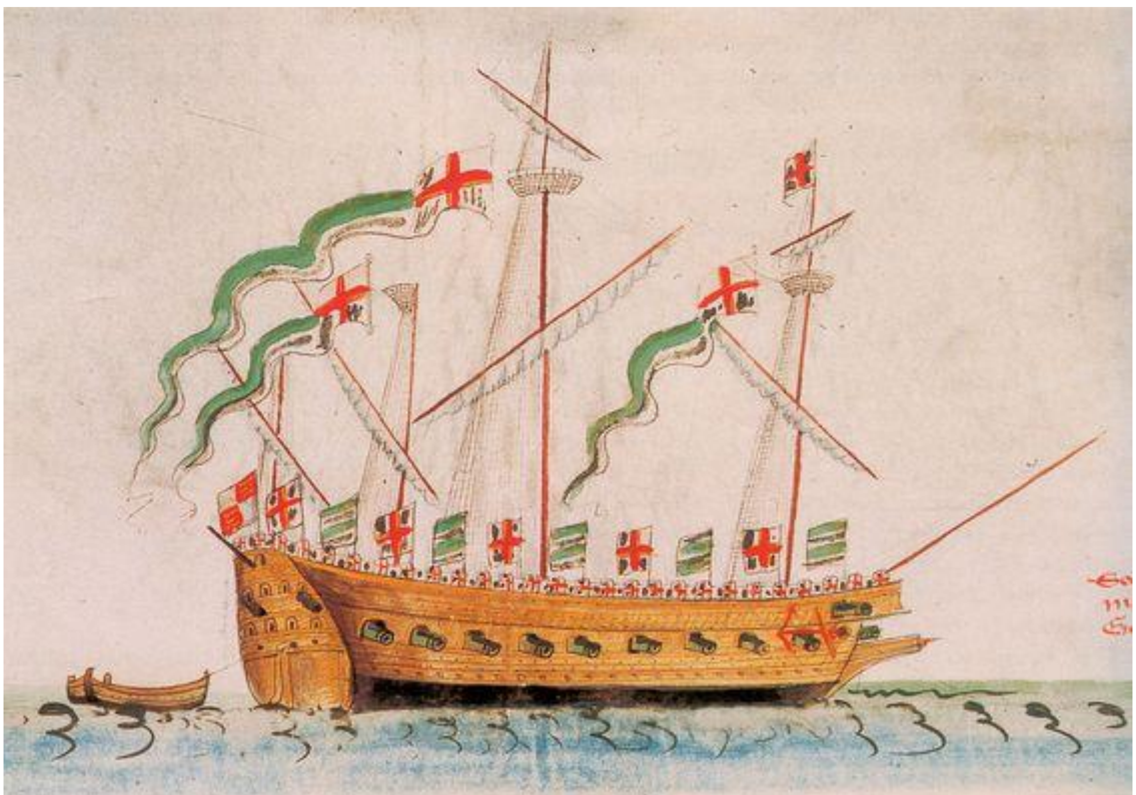

Figure 7.4. A Tudor Galleasses, the 300 ton *Hart*, from the 1546 Anthony Roll.[96] The *Hart* was under construction when Anthony Anthony produced the pictorial inventory of Henry VIII's navy, but she was included in the roll. This hybrid sailing ship was built low in the water galley fashion and was powered by either a full sailing

[95] The illustrated Anthony Roll of 1546 features a number of galleasses – the *Grand Mistress*, *Greyhound*, and *Ann Gallant*. It even pictured galleasses under construction, but not yet completed: *Antelope*, *Hart*, *Bull* and *Tiger*.
[96] Anthony Roll as reproduced in The Anthony Roll of Henry VIII's Navy: Pepys Library 2991 and British Library Additional MS 22047 with Related Documents ISBN 0-7546-0094-7, https://upload.wikimedia.org/wikipedia/commons/thumb/5/57/AnthonyRoll-23_Hart.jpg/1280px-AnthonyRoll-23_Hart.jpg.

rig or with oars. Although not seen, the oars or sweeps would project through the oar holes shown below the gun deck. Rodger notes that this ship and her sisters were referred to as 'fast wingers' and were probably intended to check the galley 'wings' of the French fleet.[97] It has a simple flush deck, a continuous gun deck, and large bow mounted cannon. It also is fitted with a ram and boarding platform forward.

The up-gunning of galleons, the increasingly destructive capability of naval ordnance, and the adoption of recoil firing technology, inexorably led to the creation of the ship of the line. There were only so many guns that could be crammed into the front of a ship. As guns grew heavier, in an era of timber ship construction, shipwrights responded with heavier decking and bracing to handle the recoil, and stronger planking to absorb enemy shot.[98] Larger guns required larger gun crews and both required more stowage space for supplies. However forward attack tactics were not amenable to large broadside mounted gun batteries.[99] The emerging ship of the line, built to awe enemies and enhance the prestige of kings, predated the fighting doctrine for which the ship-type is named.

Privileging firepower over boarding tactics did not fully capitalize on the enormous broadside batteries of these new massive ships. Elizabethan melee tactics or hit, run, and reload sorties both underused the larger ship's capacity and left its bow and stern exposed. It would require the development of the 'line of battle' to fully capitalize on the capabilities of these ships.[100] Heavily armed, heavily built ships, aligned bow to stern, a cable's length apart, massing fire against close ranged targets, would constitute the line of battle. This form of battle would not just require different ships, but a more disciplined and hierarchal officer corps. Advances in signaling were coupled with rigid compliance to command and formation – the independent and

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[97] Rodger, *Safeguard*, 212.
[98] Ibid, 389, notes that the English also developed lighter, shorter cast iron guns which also spurred ship up-gunning and easier recoil (and therefore reloading).
[99] Guilmartin, 163-164. The transformation of galleon to ship-of-the-line began in the 1630s.
[100] Dull, Johnathan R., *The Age of the Ship of the Line: The British and French Navies, 1650-1815*, 2, notes that the concept of ships sailing bow to stern for mutual support was not entirely new, and as others have observed, Vasco da Gama employed line ahead tactics in a battle in the Indian Ocean in 1502. However these tactics were designed to protect the Portuguese from boarding attacks by more numerous local ships, they were not meant to be used to maximize ship smashing broadsides directed at other heavily gunned stout ships. Boarding, melee, and fire-ship tactics predominated in European naval fights until the Anglo-Dutch wars.

autonomous sailing captain was being molded into the shape of his infantry compatriots ashore. It was the English and Dutch who first started linking gunnery and the new naval tactics. But before we address this, suffice to say that the fifteenth and sixteenth century quest to build bigger and more powerful ships evolved from the galleon led to early nautical arms races, catastrophic disasters, and ruinous fiscal policies. Kings demanded bigger and more powerful ships, and they developed institutions to provide well found fleets. This pressure led to ship "designers trying to 'push the envelope.'"[101] From these arms races came designers and shipyards which specialized in warship construction; administrative apparatuses for building, manning, provisioning, and fighting enormous fleets; and treatises on both ship building and ship fighting. Konstam brackets his naval renaissance at its inception in 1418 with the launch Henry V's *Grace Dieu* and at its conclusion with Phineas Pett's 100-gun triple deck *Sovereign of the Seas*. Konstam claims this ship was "the ultimate Renaissance 'battleship,' a warship so well armed and so well designed that she could well have stood alongside the British fleet at the Battle of Trafalgar almost two centuries later."[102] Of the two critical lessons gleaned from the Armada highlighting the importance of gunnery and maneuverability, the English sided with gunnery, and in the ensuing seventeenth century Anglo-Dutch Wars. "English design would emerge triumphant. … English ship designers such as the Petts saw that the new arbiter of victory in naval warfare would be guns, not maneuverability."[103] This conclusion would be well founded for the next

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[101] Konstam, *Sovereigns*, 5.
[102] Ibid, 2.
[103] Ibid, 277. This is a well-supported conclusion for national naval combat and fleet actions.

However, maneuverability was not completely abandoned by the English; even if it was a subordinate design characteristic in the line of battle ships that constituted the backbone of the Royal Navy.

Rodger, *Safeguard*, 390, notes that as the English worked upon larger and more heavily gunned ships of the line a new ship type was evolving out of the galley. Dunkirker pirates fixed the galley hull form with the square sailing rig of a ship creating a marvelous raiding vessel. They were lightly armed, heavily manned, and fast.

Glete, 179, notes that the frigate developed in Spanish Flanders in the 1620s by local shipwrights. It was light, well-armed, and had a higher speed under sail. It was quickly imitated by the Dutch and eventually the British. He notes, that "north-western Europe was a regional center for technical development where ideas spread several hundred years of naval combat. This period could also boast the innovation of one of the most remarkable ships of the Age of Sail, the frigate.

The Frigate

The frigate was a ship emblematic of the modernizing trends of the northern navies. The evolution of the most dexterous, politically impactful, survivable and global technological system of the Age of Sail was the product of social bargains. This compromise system was as much the driver of the spread of Western global hegemony in the early modern period as is it was emblematic of the leaders and societies of the great North Atlantic powers. Western creation of this holistic technological system was purpose structured and reliant upon social and mechanical compromises essential in cultural ascension and political dominion – this systematic approach, blending technology and the social is a hallmark of the modern Western state. Institutional destruction and creation, although never painless, was ubiquitous in the growth of the West and was essential to maintaining supremacy at sea.

In order to understand the compromises and restructuring needed to create the frigate and the officer class that wielded it, we need to return to the line of battle (LOB). The ascendancy of a dominate ship type and LOB tactics in Age of Sail left a major utility gap which fostered Western generation of the frigate. The need became painfully apparent to England during its seventeenth century wars against France and Hapsburg Dunkirker commerce raiders.[104] This

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rapidly without being limited by national or religious borders." These Dunkirkers were the cutting edge of Hapsburg naval power.

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ability to adapt technology, accept technological disadvantages and innovate independent command structures, rather than forcing reliance on preeminent systems offered a flexible, economic, and ultimately paradigm shifting alternative technological trajectory to emerge.

The frigate was born as a compromise – speed, gunnery, survivability, manning, range were all judiciously balanced to create a ship that was "able to beat anything they could catch, and out-sail anything they could not beat."[105] It evolved with LOB tactics. Frigates served as the eyes of fleet in Europe, as the nation's flag abroad, and as the mainstay in the very modern evolving economic warfare centered on the world's oceans. It filled the primary roles of both commerce raiding (*course de guerre)* and convoy protection. Frigates became the economical ship of choice for emerging naval powers from the American Republic to a resurgent Ottoman Empire. They were instrumental in piracy suppression from Tripoli to the Caribbean and in Britain's socially inspired campaign to end the Atlantic slave trade.[106]

The frigate was also a system which was continually being adapted and improved upon. These ships grew and shrank and settled in upon a somewhat standard size and armament,

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The frigate would never eclipse the ship of line during the Age of Sail, but it served an essential role as scout, commerce raider, convoy escort, national emissary, and explorer. It would also be the only ship-type to survive the age of sail, evolving into the armored cruisers of the modern era.

[105] Lardis, Mark, *British Frigate vs. French Frigate, 1793-1814*, 4-5. Despite this clever witticism, ships of the line could usually out-sail frigates especially in gale force winds.

[106] Klein, Herbert S., *The Atlantic Slave Trade*, 1999, 8th Printing. The author downplays the military effectiveness of the UK naval campaign on the economics of the trade. He credits a 10% reduction in volume (199), a capture of 1,871 vessels (159) and a shipping cost increase from 15% to 50% of the total trade revenue (200), but calls the naval efforts a "minor deterrent" (201). Klein concedes that the will displayed by the UK through the use of the Royal Navy demonstrated its political commitment and forced various governments to honor their treaties (199). However, he still claims that the trade was ended not so much by a "force of arms … as [to] a profound change in world opinion" (202).

The facts belie that conclusion. Brazil only capitulated after the Royal Naval imposed a coastal embargo and raided its ports (190). The French only capitulated after their defeat at Waterloo (187). The Spanish only stopped the trade in 1867 because they were afraid they would lose Cuba to the US or possibly face a UK invasion (192). Numerous actors ended this odious trade. Quakers, British Parliamentarians (e.g. Wilberforce), and British diplomats were indisputably critical in this effort. However, their efforts would have been in vain without the sacrifices of the Royal Navy. Moral suasion without the credible threat and often the judicious use of force is simply posturing. This was as true in the nineteenth century as it is today. Sadly Western elites have forgotten this truism and have also forgotten that slavery was ended in the United States by the bayonets and blood of the great armies of the Republic, while at sea the trade was remorselessly attacked by the Royal Navy.

until the heavy frigates of the new American Navy ushered in the last great sailing frigate compromise breaking the 32 and 74 gun paradigm of the world's dominate navies. LOB represented the culmination of Age of Sail ship-type and doctrine for European power politics, where the frigate represented the flexibility, global reach, and global ambition of the same age. The frigate was used to push the scientific envelope and was a product of both the Renaissance sailing apogee and of the emerging scientific and mathematized early modern period. The eventual evolution of armored frigates in the mid-nineteenth century steam and iron navies to the late nineteenth century and twentieth century battleship would signal the eclipse of the ship of the line, but the frigate would continue its modernizing revisions into today's nuclear navies.

Echoing Carlo M. Cipolla's theme in *Guns, Sails and Empires*, the lethal combination of sails and gunnery propelled Europeans to global dominion. The story of sailing ship evolution is one of emerging and obsolescing technologies and epistemologies: galleys to sail, size versus maneuver, melee warfare to ranged heavy gunnery, durability balanced against speed, and hybrid multipurpose armed merchants eclipsed by purpose-built warships – durable well founded and weatherly gunnery platforms of enormous size, created for the sole purpose of battering any opposing naval force into oblivion. Privateers and merchants, called upon throughout the medieval period and Renaissance to buttress their nations' naval adventures or defend their shores, would give way as well, to a cadre of professionally trained technical naval officers. As naval shipping evolved, so did its officers and sailors, and so did the societies involved. Once again we see the maritime program both being changed by and changing society in Early Modern England. This evolution is also evident in the practice of ship design and building, and its transformation from craft and trade, to science and industry.

Ship Design

We can glimpse during the late Tudor period the beginnings of scientific ship design. For centuries ships had been crafted individually by shipwrights who laid the keel and structured the hull or skeleton directly at the building site. However, Matthew Baker, the son of James Baker, one of the first Master Shipwrights appointed 'by Patent', by Henry VIII, pioneered the practice of designing a ship on paper.[107] The elder Baker has been credited with designing many of Henry VIII's ships and with placing the guns on the ship's lower levels. His son's innovation would make possible building ships by class, using standardizing parts, estimating materials, and replicating exceptional innovations, while avoiding old design flaws.[108] The process was so novel, that it was also quickly made into a state secret.[109] However, this did not prevent Baker from recording his accomplishments in a pseudo sales portfolio assembled during his lifetime and preserved by Samuel Pepys. Konstam notes that "in his *Fragments of Ancient English Shipwrightry*, Matthew Baker published a treatise that laid out the geometric proportions he had used in ship construction. This formula revealed just how scientific the art of shipbuilding had become."[110] However it also heralded an end to the guild secrecy that was essential to most

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[107] Johnston, Stephen, "Making Mathematical Practice: Gentlemen, Practitioners and Artisans in Elizabethan England," Chapter 3: Mathew Baker and the Art of the Shipwright, 107-165, notes the truly innovative accomplishment of Baker which transformed the craft of ship building into a managed industry. By transferring design from the shipyard floor, where hitherto craftsman had laid out their hulls as they built them, to the drawing room, Baker accomplished a number of things with his paper designs: (1) drawn plans provided records and reference points, (2) they provided a cheap testing zone for different hull shapes and ship proportions, (3) they had pedagogic value for aspiring apprentices, (4) they provided administrators and policy makers tools to gauge cost and efficacy, and (5) these plans provided the master builder with a sales portfolio to sell his accomplishments.

Rodger, *Safeguard*, 219, notes that by the 1580s "English shipwrights were developing techniques of design on paper." He cites Matthew Baker's plans for the *Galleon Leicester*, as the first ship built from paper plans. The ship was started in 1578 and modelled after Queen Elizabeth's *Revenge*. He adds, 387, that by the 1630s "plans on paper were now standard."

[108] Ferreiro, Larrie D., *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600-1800*, 40-43, notes of Mathew Baker in the 1570s that "Ship plans offered administrators a means of standardization and control by giving the constructors a relatively inexpensive and quickly produced template to follow." They also allowed shipwrights to estimate load waterlines for gun port freeboard and draft requirements.

[109] Rodger, *Safeguard*, plate 31.

[110] Konstam, *Sovereigns*, 236, cites 1582 as the original publication date.

medieval craft communities. Competition for private or public building contracts was fierce and Baker had a long simmering feud with Tudor England's other great shipwright, Phineas Pett and his family. Advertising one's expertise and accomplishments in print was becoming an essential part of commercial or government contract competition.

Baker, who was appointed master constructor under Queen Elizabeth I, also incorporated a more sophisticated mathematics to his trade than the arithmetic which had dominated the practice of mediaeval ship building. Larrie D. Ferreiro, in his *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600-1800*, notes that "in the 1570s the British constructor Matthew Baker would instead calculate the proportions using fractions and cube roots, and also used these techniques to calculate hold volumes for cargo tunnage." Ship design was not just becoming documented, it was becoming mathematized. Ferreiro continues, "To this end, in 1615 Baker's colleague John Wells began employing logarithms in the calculations, only a year after their invention by the British mathematician John Napier." [111] Baker developed the first British system for gauging a ship's tunnage (burthen) by using the principal dimensions of the hull. This system was used for estimating a merchant ship's carrying capacity and was adopted by the navy in 1592 to describe the size of its warships, first called the 'direct rule' and

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Ferreiro, 41, cites the date as 1570, and elaborates that this unfinished work contained drawings of ships that he and his father had built 20-30 years earlier. Drawing upon Barker, he notes the fragmentary work was incomplete and probably co-authored later in its life by Baker's colleague John Wells.

Barker, Richard, "Fragments from the Pepysian Library," *Revista da Universidade de Coimbra*, **XXXII**, 161-178, notes that it contains "160 pages of largely disconnected text and diagrams interspersed with some very fine draughts of ships. ... It was written by two men in the period 1570 - 1630, and bound in its present form by [Samuel] Pepys some 30 or more years later. It seems clear that the document was begun as a presentation volume with a clear style and layout, but that it quickly degenerated into a notebook. At some stage it changed hands and was added to by the second author [John Wells]."

[111] Ferreiro, 43.

Johnston, 15, notes that Baker although creating formulas requiring cube roots, more often than not provided guidance on using approximations to get within one tenth of the exact number, and that he also stressed the importance of using geometric scales as a supplement to brute mathematical calculation before the advent of Napier's logarithms.

later 'Mr. Baker's old rule.'[112] Baker also expounded upon the shape of ship hulls and posited that their most efficacious shape could be ascertained by mimicking fish.[113] Drawing upon design lessons offered by nature was not entirely new, but studying natural history for the advancement of technological development would become one of the emblematic features of the Scientific Revolution.

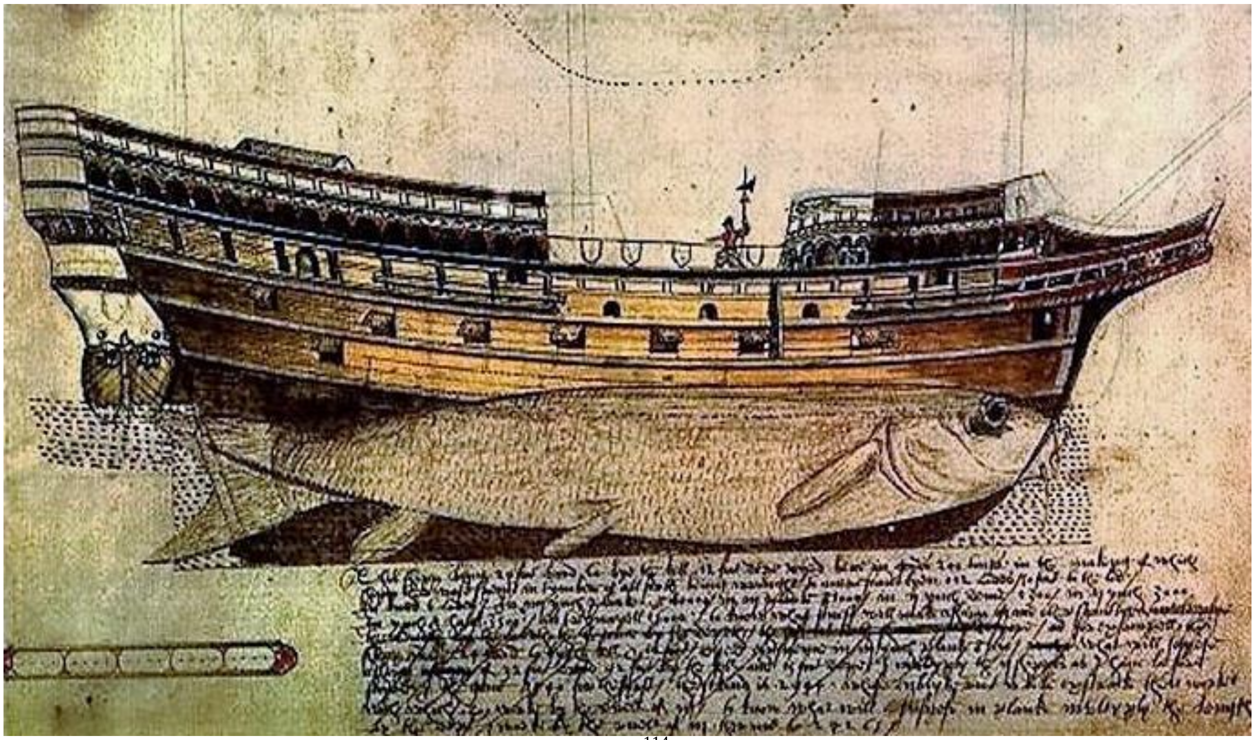

Figure 7.5. Matthew Baker's Fish Inspired Hull Design.[114] From *Fragments of Ancient English Shipwrightry* (c. 1570), this drawing by Baker details his theory about why the most efficacious hull design featured a wide hull forward and a tapered aft section. The fish superimposed over this hull aligns nicely with the tapered dead wood of the keel. However, Ferreiro insists that the hull shapes contemplated by Baker were not based upon the modern theory of resistance – this linkage was first proposed by Isaac Newton.[115]

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[112] Ferreiro, 193.

Johnston, 12, notes "the rules he devised for tonnage frequently called for the extraction of cube roots. Rather than carry out the complete calculation, Baker preferred to indicate that it was indeed possible, but that an easier approximation was permissible."

[113] Ferreiro, 123-124, notes that ship hulls should have "the broadest section forward and tapered aft, commonly cited as 'cod's head and mackerel's tail.'" He adds the interesting observation that while Europeans mimicked fish in their hull forms, the Chinese used aquatic birds as their design inspiration.

[114] "O Liuro da Fábrica das Naus," Nautarch.tamu.edu, http://nautarch.tamu.edu/shiplab/01George/Oliveira.htm.

[115] Ferreiro, 127.

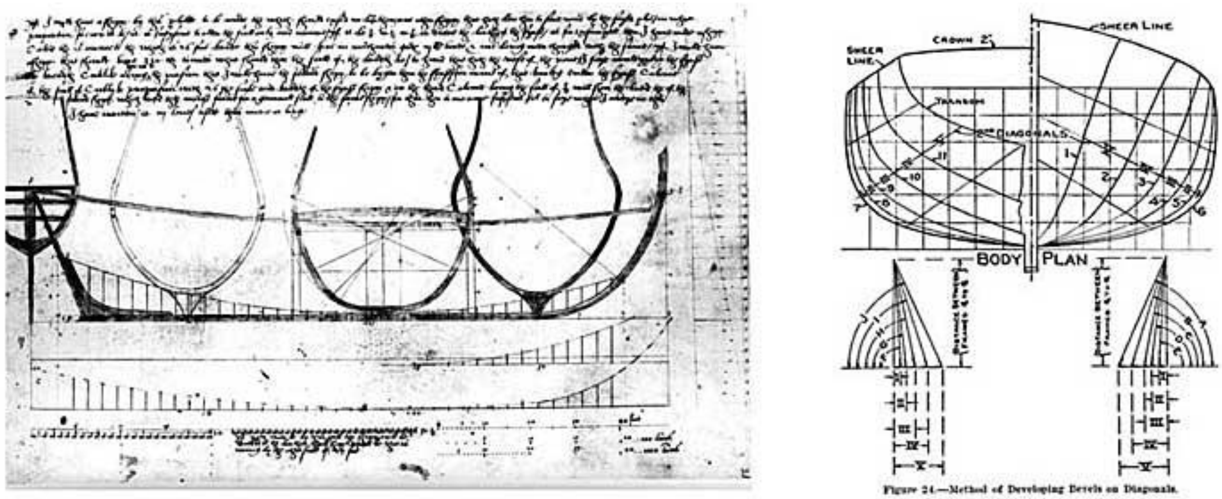

Figure 7.6. From Craft to Science: Matthew Baker's technical drawings from *Fragments of Ancient English Shipwrightry* linking mathematics and ship design were pioneering efforts and the first step in the ascent of naval architecture from craft to science.[116]

Baker was emblematic of the modernizing influence that the maritime world was having upon English society. He was mathematizing his craft and elevating the status of shipbuilders and himself in a crucial strategic industry. By depersonalizing the supervision of ship crafting and systematizing its construction through the medium of paper design, Baker was a forerunner of the modern industrial manager. His advocacy of incorporating mathematics in design earned him praise and collaboration from gentleman mathematicians like Thomas Digges and Thomas Harriot. He was also consulted and cited by mariner philosophes like Richard Chancellor, the Borough brothers, and John Davis. Stephen Johnston asserts that due to Baker, "the shipwright was now to be identified as a mathematical mechanician."[117] He adds, "The development of the paper geometry and arithmetic of *Fragments* rapidly made English shipbuilding the most

[116] Johnston, 107-165, "Mathew Baker and the Art of the Shipwright," Mhs.ox.ac.uk, http://www.mhs.ox.ac.uk/staff/saj/thesis/baker.htm.

[117] Ibid, 13-14, notes that Baker spanned several generations of English nautical endeavors. He sailed to the Mediterranean on one of England's pioneering voyages with Richard Chancellor in 1551, he built the *Judith* for the Boroughs, and he was active with the premier English mathematician of the seventeenth century, Thomas Harriot.

mathematically advanced of any country in Europe."[118] These technically prompted social changes were not limited to England.

French Ship Theory

As their naval power grew, the French as we have observed, responded in kind. Although France never could boast the long-term steady commitment to maritime prominence of her cross-Channel rival, she did have periods of furious naval accomplishment, especially under the direction of Louis XIV's Colbert. Under his supervision naval exigencies spurred government sponsored scientific inquiry and observatories. He centralized naval construction as part of Louis XIV's overall trend toward consolidation of power, but as a result we observe the evolving professionalization and rise of new middle class engineers required by the state. Like their contemporaries in the navigation, they produced training curriculum and scientific results 'black boxed' for use by less educated functionaries.

By 1765 France had militarized its construction corps, elevated its chief constructors into the petty nobility and set the standard for institutionalization which would be adapted by navies throughout the West.[119] In addition to these enduring institutional legacies, they developed mathematical ship building theories which were well ahead of their time and usefulness.[120] However, Ferreiro notes that unlike British methods, French design theories "did not have any practical effect on ship design during the 1700s."[121] Ironically, it would be the engineers of

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[118] Johnston, 20.
[119] Ferreiro, 290.
[120] Ibid, 187, notes that of the scientific design theories developed in the period, only Bouguer's metacenter (the initial measure of ship stability measured as an imaginary point in relation to the ship's center of gravity) survives in today's design process.
[121] Ibid, 249. British ship design was driven by tactical considerations, 97, "British tactical thinking tended to be dominated more by practical considerations such as signals, rather than geometrical constructions of maneuvering." Whereas the French used scientific tactics of *derivé* calculation and deriving point *vélique* when designing ships. He gauges the results of the respective approaches, 296, by noting that "The British navy was producing what were arguably the most successful warships on the planet, winning the majority of engagements and capturing five times

Industrial Revolution England that would use and expand ship theory (through experimentally derived data) for their iron and steam ships of the nineteenth century, before ship theory and naval architecture would indeed provide qualitative advantages to its practitioners.[122] But it is important to note that the new ship theory was on the frontier of scientific inquiry of the day.[123] Clean bottoms and trained crews impacted speed more than any theoretical improvement derived from these debates, but the institutions of education and training of constructors and the grounding of future improvements in mathematics were established during this period. However, as the seventeenth century dawned, England was not just leading the world in navigation science and ship design. It was also making major advances in ship maintenance through advances in civil engineering.

Dry Dock Technology

Concomitant with advances in ship design, Tudor England was also pioneering the development of dry dock technology. Throughout the Middle Ages in northern Europe, ships were built in 'mud docks' – either on shore, beached at high or spring tide, or in an excavated inlet, protected by a watertight earthen dockhead. "Like warships themselves, the docks and slips necessary to support them were among the most costly and sophisticated possessions of any medieval monarch."[124] These mud docks required immense amounts of labor to excavate for large ships, more labor was required for launching, and they required extensive draining and

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as many enemy ships as its nearest rival, France – all without the benefit of the metacenter or the calculus." However, one should note that he is treating the ship as a discrete causal actor as opposed to a part of the officer-crew-ship-tactical system that produced the aforementioned result.

[122] Ferreiro, 257.

[123] Ibid, 129-131, it included Newton's erroneous 'shock theory of force' and the subsequent theoretical pursuits searching for the chimeric 'solid of least resistance' and calculations for the ratio of bow resistance. However, ix, he observes that "the men who developed ship theory were the same ones who expanded differential and integral calculus and solved the problems of planetary orbits, tides, vibrating strings, and ballistics; ship theory was for them part of the overall study of rational mechanics."

[124] Rodgers, *Safeguard*, 69-71.

reconstruction for multiple uses. Their unsuitability for regular ship maintenance contributed to the short lifespan of medieval ships, and the associated high expense of state navies. In order to extend the life of their ships, and to make them faster, the late Tudor naval administrators substituted the northern practice of 'graving' (beaching ships at low water to repair their hulls) with the Mediterranean practice of 'careening.' This process was conducted afloat and required heeling the ship to expose one side of the hull at a time.[125] Unfortunately this practice did not expose the keel for maintenance and on very large ships, subjected the hull to tremendous strains.

The solution to this nautical maintenance problem evolved from the fusion of existing mud dock technology and emerging canal technology. In 1578 the crown paid to have watertight gates put on a dock at Deptford.[126] This technology evolved, and as it was perfected, dry dock use was extended from major refits to routine maintenance. Rodger notes that "the installation of dock gates, which marks the invention of the true dry dock, was a very important development. It was to become one of the key technical achievements underpinning English sea power."[127] This advantage would become more pronounced as technological improvements developed, so that even when emulated by Colbert in 1666, the English maintained a distinct advantage. Dry docks led to larger and more complex ship building and maintenance operations at dockyards. As these facilities increased in size and scope, so did the size and complexity of the labor force, and the management acumen required making it productive. Rodgers notes that "the discipline

[125] Rodgers, *Safeguard*, 335.
[126] Ibid, 335, he can draw this conclusion, even though it is not explicitly stated in the records, because the recurring extensive labor bills for the local marshmen to excavate dockheads disappear from the records in the early 1580s. He also notes the non-coincidence of the contemporaneous construction of the first English pound lock on the Exeter ship canal.
[127] Ibid, 336.

of time keeping was by now well established."[128] At the turn of the seventeenth century, dockyard workers were regulated by sundials, and by the 1630s, clocks were in use at Chatham. All this occurred long before traditional historical dating of the Industrial Revolution. The requirements of maintaining an English navy at sea in the early Age of Sail were driving social developments with earmarks of modernity.

All of these innovations in ship design, building, and maintenance had dramatic impacts at sea, but also on land in English society as a whole. Bigger ships, larger fleets, heavier guns, longer cruises, global trade, and the maintenance of a large technical maritime establishment required organizations and financial resources not available to medieval states. The strain on the state reached the breaking point several times during the seventeenth century in England, and although maritime demands were not the only issues that fractured the English political world during this tumultuous century, they often played a critical role. This was especially true concerning relations with England's great maritime rival the Dutch, as we shall observe in the next chapter.

Connections

During the seventeenth century the epicenter of the oceanic maritime project moved northwards. The importance of the Iberian kingdoms waned as the Dutch and English aggressively pushed back the frontiers of knowledge in mathematics, navigation, cartography, ship design, ballistics, gunnery, foundry technology, blue water sailing, dry dock and shipyard management, instrument manufacture and innovation, and naval tactics. Elizabeth's victory over Phillip's Armada marked not just the beginning of England's tumultuous ascent on the global stage, but also the eventual preeminence of the new maritime trading class in English society.

[128] Rodgers, *Safeguard*, 375, "the dockyards were the largest and most complex parts of the naval administration, and by far the largest industrial establishments in the country."

This maritime community would imbed their values and priorities in the new administrative institutions of the modern world. Phillip's wealth and fleet, wedded to the values of Spain's aristocracy, was defeated by a fleet built for upstart pirates. Their victory both saved Elizabeth's throne, but also held her hostage to their maritime ambitions. Their success in saving the nation illustrated to the nation that satisfying their needs would deliver security and hopefully great wealth.

Late Tudor and early Stewart England focused its greatest intellectual minds and universities on resolving maritime issues. Mathematics would provide the solution to many of the pressing navigation, cartographic, and instrumentation issues befuddling mariners. The success of English mathematicians in resolving practical maritime problems would in turn elevate the status of mathematics vis-à-vis the medieval hierarchy privileging theology and metaphysics. The immediate tangible rewards of mathematical success were persuasive. Mathematical success at sea helped embed our modern epistemology whereby quantification provides the absolute arbiter of truth.

Maritime necessities spurred investigation and data collection helping cement first Copernican math, but eventually heliocentric cosmology. Cartography was adapted to distort land mass in higher latitudes to provide more efficient seaborne travel. Arduous calculation was embedded in devices, both physical and written, to propel the oceanic project. In Napier's logarithms and Gunter's scales we can glimpse our modern world were computers do the hard thinking for us, and the vast majority of the population use tools created by a tiny intellectual elite. We also see the increasingly complex craft of ship design both mathematized and simultaneously removed from the realm of the craftsman. The exigencies of naval combat, its enormous cost, and global distances, made both standardization and reliable replication essential.

Matthew Baker helped create the modern distinction between design and craft. By removing design from the physical shipyard and putting it on paper, he shattered a paradigm spanning millennia. Design and art were now becoming intellectual and mathematical pursuits, the actual building was left to craftsman. Another new class, the designer, was emerging between policy makers and doers. The maritime project and the expanding middle-class of modernity grew symbiotically.

However, the social order was also undergoing rapid change in the Dutch Republic. Events in England and on the continent would end the sixteenth century sectarian alliance, erupt in decades of mercantile rivalry and open war, and eventually result in a political fusion that would herald England's rise to global prominence. And that is where we will follow our story.

CHAPTER 8.
Dutch Wars and Organized Science: Imitation and Innovation in the Seventeenth and Early Eighteenth Centuries

Dutch Wars, Invasion, and Imitation

When James Stewart of Scotland succeeded his cousin (twice removed) and the executioner of his mother in 1603, he assumed the mantle of James I and VI of England and Scotland respectively. He also inherited a naval tradition centered upon piracy that he loathed. However, peace with Spain did not bring an end to either English or Dutch piracy in the north Atlantic.[1] The lawlessness of these pirates, the size of their fleets, and Barbary slave raids on coastal Channel villages and Newfoundland fishing fleets prompted public approbation. James responded by drawing from Scottish law the concept of enforcing sovereignty (and tax jurisdiction) over 'territorial waters'. However, this was impossible to enforce in practice as the Tudor Navy Royal had seriously deteriorated during James' reign. After fifteen years of neglect, James attempted to restore his navy and achieved much with his Navy Commission of 1618. However, by the time Charles I ascended to his father's throne, six years of the financial and logistical demands of the increasingly modern warfare fought in Europe against Spain and France from 1625 to 1630 collapsed the nascent infrastructure his father's commissioners had rebuilt.[2] Cardinal Richelieu had created a French navy from nothing in five years which outnumbered the English fleet, as did the navies of Spain, the Netherlands, and Algiers. England was declaring sovereignty over its adjacent waters without the wherewithal to enforce its bellicose claims.

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[1] Rodger, *Safeguard*, 347-350, refers to the years 1608-1614 as the "heyday of these English and Dutch pirates," noting that they sailed in fleets as large as state navies. It was their size and lawlessness, combined with the arrival of Barbary pirates and slavers preying on English coastal villages that started to turn English public opinion against total lawlessness at sea.

[2] Ibid, 372, "By the peace of 1630 naval administration had passed through three distinct phases since Queen Elizabeth's death: fifteen years of neglect and decay, six years of retrenchment and reform, and a further six of desperate wartime improvisation and deepening crisis."

Charles addressed this threat by creative financing (see Financial Innovation section below) and through the construction of larger and larger heavily gunned galleons which eventually became the ships of the line of the next two centuries. However, his failure to protect English coastal shipping and long distance trade helped exacerbate parliamentary resistance which was steadily building due to Stewart religious toleration of Catholics and repeated attempted rapprochements with Spain. Naval strategy disputes did not cause the religious rifts of the era, the dismissal of parliament, or the ensuing civil war. However, when Parliament gained control of the Navy in 1642, they immediately replaced Charles's big ship paradigm with a "'home policy' Navy of smaller ships for the defense of trade and the coast, which Charles I had not chosen to build."[3]

At the same time the Dutch were busy building up their truly innovative joint stock global trading companies; Holland's East Indies trader, the *Vereenigde Oost-Indische Compagnie* or VOC (1602), and Zealand's West Indian trading company, the *Westindische Compagnie* or WIC (1621).[4] Up until this time, the Dutch had "showed little interest in plunder and interloping trade against Spanish and Portuguese interests overseas."[5] However, the early

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[3] Rodger, *Safeguard*, 421.

Glete, 179, notes however, that Charles I's policy was not abnormal for the time and that "the Dutch navy was the only navy in Europe which was primarily deployed for trade protection."

Rodger, *Command*, 32, notes the role the navy played in its early support of the Parliamentary cause, but more significantly, he contends that "in 1660 its refusal to fight for the Republic opened the way for Charles II's restoration."

[4] Robson, 33, notes that the French also initiated an Indies trading company in 1604 (*La Compagnie des Indies*) when King Henry IV granted it a fifteen year monopoly. This effort was essentially stillborn for sixty years until Colbert launched the *Compagnie des Indies Orientales* and obtained a charter from Loius XIV. The French built the port of L'Orient (Lorient) for the company to include warhouses and shipyards. Its success was mixed, as were that of its private and state owned successors.

[5] Glete, 168-170, notes that the companies "were innovative successful organizations for overseas warfare which attempted both to attack the enemy and protect and promote the companies' own economic activities."

Guilmartin, 191, in 1598 Philip III tightened up the Spanish embargo of Dutch commerce and ordered Dutch ships seized. "In doing so he sowed the wind, and his empire would reap the whirlwind. Hitherto the Dutch had showed little interest in projecting violence abroad for profit, preferring peaceful commerce instead."

Schmidt, 172-173, opines on the martial underpinnings of the WIC and its "stated aim to take the war to Spain's American underbelly." He notes that the WIC helped fight the Dutch war against Spain and that the States General at critical moments contributed men and ships to WIC operations.

seventeenth century Spanish strategic shift, emphasizing embargo and commerce warfare against their rebellious Dutch subjects, not only highlighted the inability of Spain to deploy a credible northern fleet that could impose its will on station, but it also had the catastrophic unforeseen consequence of releasing Dutch predators into the Iberian global spheres of influence. Throughout the first half of the seventeenth century the Dutch launched a relentless trade war targeting vulnerable Portuguese and Spanish trading posts and shipping across the world. Their success also signaled the definitive end of the carrack and the Portuguese nao. Glete notes that these ships "were vulnerable to weather if they sailed in the wrong season. Their large size, intended as a protection against Asian attacks with a large number of men, was no advantage when they were attacked by the smaller but well-armed Dutch East Indiamen."[6] The Dutch brought North Atlantic technology and naval tactics into an ossified Iberian mercantile trade zone and shattered it. Their trade war was so successful that in 1627 the WIC realized the dream of fifty years of English Privy Councilors and pirates when they captured the entire Spanish *flota* off the Azores.[7]

When Cardinal Richelieu committed France to the Protestant side in the Thirty Years War in 1635, the 'Spanish Road' to Flanders was effectively severed. For several years the Spanish were able to relieve their forces in Dunkirk by sea. Emboldened by this success, they led one last great Hapsburg armada in 1639 into northern waters to crush a Protestant upstart. This armada was effectively annihilated by Maarten Tromp while the Channel fleet of Charles I protested and spectated, but did little else. Unlike the Spanish Armada of 1588, which was worn down by the English but eventually destroyed by Atlantic gales and the Irish coast, this armada was destroyed by Dutch gunnery using line-ahead tactics to close on the disorganized but

[6] Glete, 171, adds that the "Portuguese inability to modernize their shipping technology is an interesting case of inertia in an established organization."
[7] Rodger, *Safeguard*, 361.

numerically superior Spanish, and then luffing up to discharge rolling broadsides in succession.[8] The Dutch victory at the two actions that constituted the Battle of the Downs ended forever Spanish naval ambitions in the North Atlantic. Within a year they also lost control of their Portuguese vassal. Coupled with the success of the VOC and WIC abroad, it also clearly illustrated that the Dutch were Europe's leading naval and merchant power.

At the same time, the Dutch were also building up a highly profitable North Sea herring fishery.[9] This fishery, like the English and Breton fisheries off the Newfoundland Banks, produced not just fish, but mariners.[10] P.G. Rodgers, in his classic analysis of the Dutch raid on the Medway during the Second Anglo-Dutch War observes the following:

> "[The] extraordinary achievement of the Dutch, that whilst they were fighting for their existence as a separate State, they were able to make that State the leading commercial and colonial Power of the seventeenth century. The foundation of this achievement was, prosaically, the humble herring."[11]

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[8] Guilmartin, 199-203, notes that all Spanish attempts to grapple and board were warded off by the tight discipline within the Dutch formations. They were still wedded to the concept of warships as infantry platforms. However, he also notes that Tromp used line-ahead tactics in the first encounter where he was severely outnumbered "as a defensive expedient in desperate circumstances." He notes that in the more evenly matched second encounter Tromp, like Howard at the Battle of the Gravelines in 1588, used fireships and mêlée tactics for the *coup de grâce*.

Glete, 181, notes that the Spanish Admiral, Antonio de Oquendo, the son of an Admiral in the 1588 Armada, had the weather gauge and intended to fight with muskets and boarding – a classic infantry operation. The dramatic disparity in fleet sizes and results after so much close fighting can only be ascribed to a "vast difference in naval culture. The Spaniards seem to have lacked firepower, seamanship and the tactical imagination to use a much superior force in combat."

[9] Rodger, *Safeguard*, 351, the 'Great Fishery' or 'Dutch Indies' earned one million pounds per year and employed 20% of the population of the Netherlands.

[10] Guilmartin, 196, notes that in the ensuing Hapsburg naval assault on the Dutch in their home waters they had the sympathetic neutrality of Charles I and every advantage in resources, "with the sole and vital exception of seamen." The abundance of Dutch mariners he attributes to "flourishing trade and fisheries." English statesmen and naval strategists made a similar claim for at least a century going at least as far back as Dr. Dee and which led to repeated Parliamentary exemptions from naval impressment of men involved in England's fishing fleets.

[11] Rodgers, P.G., *The Dutch in the Medway*, 4, adds that it was a medieval technological breakthrough in preserving herrings – pickling or curing them with salt – that enabled these fish to be traded as a commodity. This trade, largely with the Baltic nations and often conducted in exchange for shipping resources – timber, tar, hemp, etc. – enabled the Dutch to dominate the European coastal carrying trade.

Richard W. Unger expanded upon this theme a decade later in an article titled "Dutch Herring, Technology, and International Trade in the Seventeenth Century," *The Journal of Economic History*, **40:2** (1980), 253-280. He notes that the fishery was a "transforming industry, a *trafiek*." The Dutch caught the fish, used imported salt and barrels made from imported wood to cure and package them. The herring were traded for Baltic products resold in France and Iberia for salt, wine, and luxury items. The trade was extensive, elaborate, and involved complex international networks, but at the center of all of it was the Netherlands. The 'Great Fishery' was not a commodity production operation, but a continental economic system.

This extensive fishery, supported by a sophisticated curing and packaging operation, extensive Baltic trade routes, and a large supply and distribution coastal trade network, enabled the Dutch to dominate the supply of this commodity and to virtually monopolize the coastal carrying trade in Europe. By the middle of the seventeenth century the Dutch controlled seventy-five percent of European regional maritime trade.[12] This tiny Republic, with a population of two million people had accomplished in Europe, what its aggressive quasi-militaristic trading companies had achieved across the Iberian global empires. As Schmidt notes, "Above all, Dutch merchants profited from the transit trade: the movement of goods from port to port, which facilitated the various Atlantic economies rather than any specific Dutch colonial presence."[13] The Dutch became indispensable and wealthy, not by creating empires, but by servicing the inadequate sea lines of communication of Europe's great powers. The Dutch assiduously tried to maintain their neutrality, and had no scruples about trading with even their own existential enemies. It was only when confronted with the aggressive attempt to destroy their trade in the early seventeenth century that they adopted a hostile and imperial posture.

The success of the herring fishery right off it's north-eastern coast provoked jealousy in Britain and futile attempts at disruption and taxation. P.G. Rodgers documents the early seventeenth century pamphlet assaults upon the Dutch within England, and notes that despite their vicissitude, even the most hyperbolic assaults upon the character of the Dutch and their alleged ingratitude for Elizabethan assistance in their struggle against Spain, still grudgingly note

[12] Barone, Michael, *Our First Revolution: The Remarkable British Upheaval That Inspired America's Founding Fathers*, 29, cites John Carswell, *The Descent on England: A Study of the English Revolution of 1688 and its European Background*, 11.
[13] Schmidt, 177, is focusing specifically upon the WIC in the Atlantic.

the industriousness, contractual faithfulness, and maritime acumen of their targets.[14] What emerges from these bromides is less hatred than envy. In addition, WIC success in the Atlantic and the establishment of the New Amsterdam trading colony at the mouth of the Hudson, in what the English presumptuously referred to as their colonial sphere of influence, both assaulted English pride and threatened English mercantile ambitions.[15] Furthermore, Dutch control of Baltic trade and with it access to the vast shipping commodities of that region upon which England increasingly relied, alarmed those interests concerned with shipping and the maintenance of the navy. Aggressive English trade policies and their insistence upon deference from all neutral shipping passing through the Narrow Seas helped to exacerbate tensions between the erstwhile protestant allies.[16] The Navigation Act passed by Parliament in October 1651 restricting exports out of England to English ships and imports to either those of England or the producer country severely threatened the viability of the Dutch carrying trade, at least with regard to England. However, in the final analysis, it was economic competition coupled with insufficient Dutch religious fanaticism which led Cromwell's government to declare war on the heretic Republic in 1652.[17] However, the Lord Protector's navy was neither the large ship navy of Charles I nor the coastal cruiser navy of the early Republican Parliament, but rather a fusion of the two. A decade of civil war throughout the British Isles had demonstrated to Parliament

[14] Rodgers, P.G., 10-13, cites tracts by Vice Admiral Sir William Monson among many others. He also recounts their reappearance, 22-24, during the build up to the second Anglo-Dutch War in the mid-1660s.

Barone, 64, notes that "the political pamphlet, which would be such a powerful instrument in the making of the American Revolution, was a similarly powerful instrument in England a hundred years before."

[15] Rodgers, P.G., 20, notes that New Amsterdam "was a constant irritation to Charles II," who in 1664 sent an expedition on the eve of the second Anglo-Dutch War to conquer the colony of New Netherlands, renaming its capital after his brother James, the Duke of York.

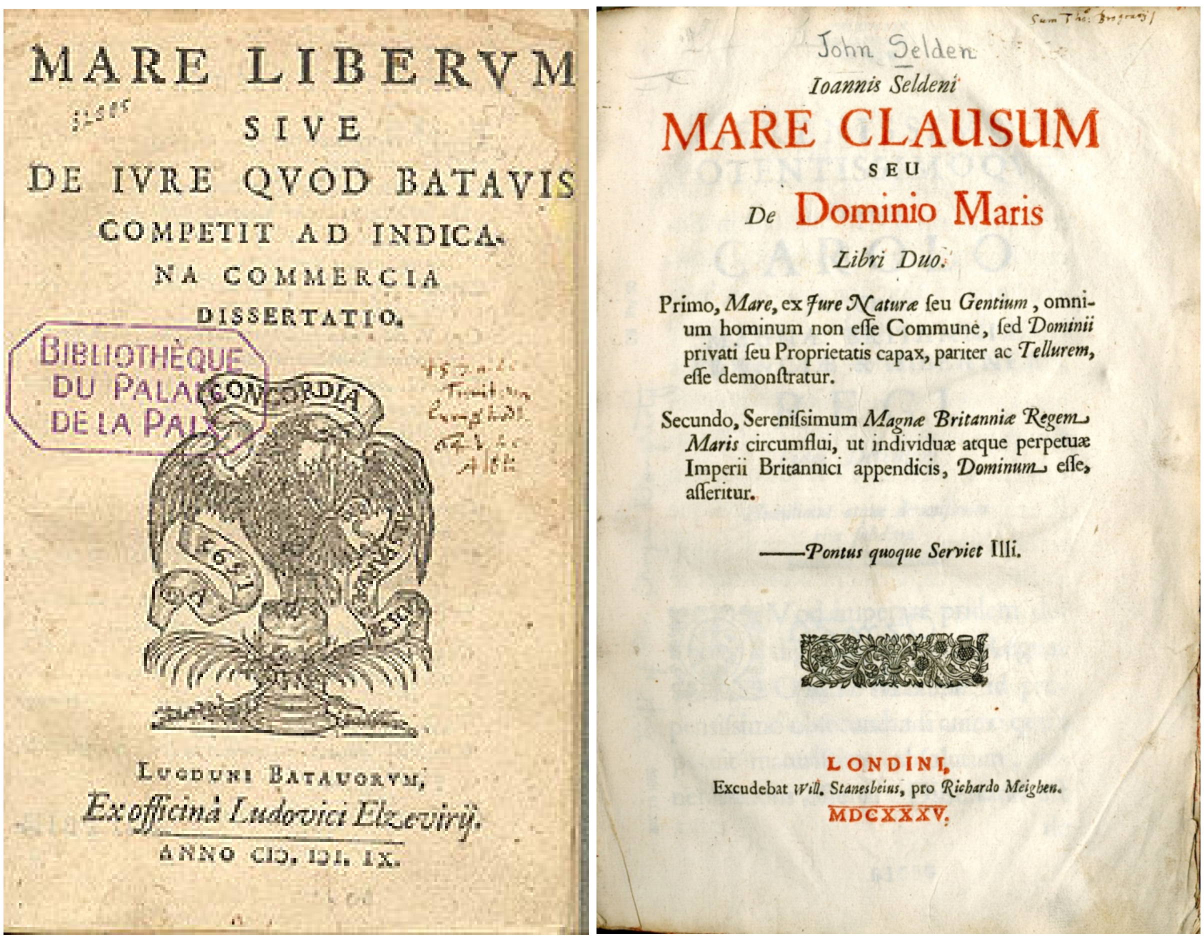
[16] Onnekink, 3, notes the similarities, "both states regarded themselves as Protestant, liberal, maritime and capitalist" which both distinguished and precariously isolated them from their larger monarchal neighbors, "especially absolutist and Catholic ones. On the other hand, economic rivalry frequently soured their ties."

Rodgers, P.G., 14, also notes, the cultural similarities, especially "that each country [recently experienced] the rise of powerful wealthy middle-class, its fortunes based on trade and commerce, whose aspirations soon brought it into conflict with the older aristocratic class whose fortunes were founded on land ownership."

[17] Rodger, *Command,* 8.

Rodgers, P.G., 8, notes that "the root cause of the growing jealousy was maritime and commercial rivalry."

that they needed both trade defense cruisers to stop rampaging Royalist privateers and a battle fleet capable of supporting amphibious operations in Ireland and Scotland and to check French naval ambitions and Royalist support in their home waters. After having denied Charles I adequate funding for his navy, the interregnum Parliament boosted taxation considerably to field a navy capable of defending both commercial interests and the aggressive military goals of the state.[18] Expenses upon the navy surpassed all previous royal spending and major ship building programs were initiated.


MARE LIBERVM
SIVE
DE IVRE QVOD BATAVIS
COMPETIT AD INDICA-
NA COMMERCIA
DISSERTATIO.

BIBLIOTHÈQUE DU PALAIS DE LA PAIX

CONCORDIA

LVGDVNI BATAVORVM,
Ex officinâ Ludovici Elzevirij.
ANNO CIↃ. IↃI. IX.

John Selden
Ioannis Seldeni
MARE CLAUSUM
SEU
De Dominio Maris
Libri Duo.

Primo, Mare, ex Jure Naturæ ſeu Gentium, omnium hominum non eſſe Commune, ſed Dominii privati ſeu Proprietatis capax, pariter ac Tellurem, eſſe demonſtratur.

Secundo, Sereniſsimum Magnæ Britanniæ Regem Maris circumflui, ut individuæ atque perpetuæ Imperii Britannici appendicis, Dominum eſſe, aſſeritur.

——Pontus quoque Serviet Illi.

LONDINI,
Excudebat Will. Stanesbeius, pro Richardo Meighen.
MDCXXXV.

Figure 8.1. *Mare Liberum versus Mare Clausum*. *Mare Liberum* (*Mare Liberum, sive de jure quod Batavis competit ad Indicana commercia dissertation*,1609) or *The Free Sea*, was written by the Dutch philosopher Hugo Grotius (de Groot) to contend that the sea was international territory and the proper sphere of free trade.[19] The treatise was initially targeted at the Portuguese monopolistic claims on East Indian trade (their *Mare Clausum*

[18] Rodger, *Command*, 5, Parliament at the end of October 1650 imposed a 15 percent levy on all custom duties to pay for convoy escorts – merchants were being directly taxed for their own protection outside home waters. He also notes, 32, the interregnum regimes built in four years (1651-5) the same warship tonnage built from 1588 to 1642.
[19] Image from "*Mare Liberum*," Wikipedia.org, https://en.wikipedia.org/wiki/Mare_Liberum.

policy) and presented as a justification for the Dutch East India Company's (VOC) often violent usurpation of that trade. It gained initial support in England and was even translated into English by Richard Hakluyt (although not published until 2004). John Seldon's *Mare Clausum* (*Mare Clausum Seu de Domino Maris Libri Duo*, 1635) or *Closed Sea (or Two Books on the Ownership of the Sea),* presented the view of the English sovereign that some seas were properly under control of certain nations and that seas were as much subject to national dominion as the land was, following Roman precedent in the Mediterranean.[20] The philosophical justification for the Anglo-Dutch Wars, with control of global trade as the main objective, was heretofore established in legalistic Latin.[21]

This new navy, officered mostly by experienced merchant (or tarpaulin) mariners and commanded by 'Sea Generals', army regimental officers appointed by the military junta actually running the state, was to become an essential part of the regime's survival, but it was never trusted by the generals, as it was generally more politically moderate than the army.[22] Massive new expenditures and ship building programs built up this navy capable of waging offensive operations and with a limited capacity to protect England's nascent overseas trade.[23] Cromwell's Robert Blake beat Tromp at the Battle of Dover in May 1652, but the ascension of Michiel de Ruyter to Dutch naval command turned the tide, starting with his victory at Dungeness in November. By the end of 1654 both sides reassessed their defeats and modified their navies.[24] The Dutch abandoned their exclusive reliance upon dual purpose Indiamen and started a large ship building program of heavily gunned purpose built warships emulating the English. The English, reeling from their defeats, appropriated more funds for the navy, gave it more autonomy, and empowered its commanders to ruthlessly punish cowardice or disobedience in

[20] Image from "The First Definitive Work on the Dominion of the Sea," Tarltonapps.law.utexas.edu, https://tarltonapps.law.utexas.edu/exhibits/selden/mare_clausum.html.

[21] Konstam, *Sovereigns*, 281, Dutch *Mare Liberum* (1609) versus *Mare Clausum* (1635).

Rodgers, P.G., 24, notes that "the second Anglo-Dutch war was the result of determination by the mercantile interests in both countries to interpret the theory of *Mare Liberum* and *Mare Clausum* elastically, as it best suited their own purposes." The Dutch fought for control of territorial seas in Indonesia and West Africa while demanding open European and Iberian Seas. The English likewise demanded recognition of their sovereignty in the Narrow Seas (the English and Irish Channels, 8) and North America, but fought for open seas in the Caribbean, the Eastern Spice Islands and in West Africa.

[22] Rodger, *Command*, 2-3, notes the first three men to hold the position General at Sea, Edward Popham, Richard Deane, and Robert Blake, were "reliable regimental officers, but they were unequivocally junior in rank to the senior officers of the army, and two signatures were required for their orders: none of them was trusted to act alone."

[23] Rodger, *Safeguard*, 362, However, Spanish 'Dunkirkers' still wreaked havoc on English merchant shipping, taking 300 vessels in five years – up to 20% of English merchant fleet – until the port was captured by England.

[24] The battle is also referred to as the Battle of Goodwin Sands and was fought on the May, 19, 1652 Gregorian or May 29, Julian Calendar.

action.[25] More important however, was the appointment of a more senior army official, Lieutenant-General George Monck, to become the third General at Sea. Monck, after witnessing the chaos of the Battle of Portland, became instrumental in imposing discipline on naval battles by creating the rigid rules for maintaining a line of battle and capitalizing upon English gunnery advantages. The following English victory at Texel [the Battle of Scheveningen] on July 31, 1653, and the death of Tromp, muted further tactical arguments over the efficacy of gunfire.

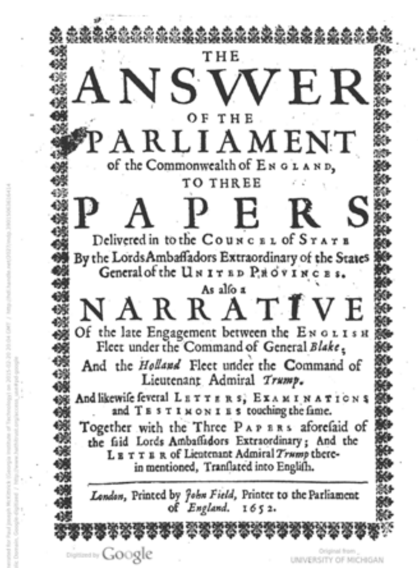

THE
ANSWER
OF THE
PARLIAMENT
of the Commonwealth of ENGLAND,
TO THREE
PAPERS
Delivered in to the COUNCEL of STATE
By the Lords Ambaſſadors Extraordinary of the States General of the UNITED PROVINCES.
As alſo a
NARRATIVE
Of the late Engagement between the ENGLISH Fleet under the Command of General *Blake*;
And the *Holland* Fleet under the Command of Lieutenant Admiral *Trump*.
And likewiſe ſeveral LETTERS, EXAMINATIONS and TESTIMONIES touching the ſame.
Together with the Three PAPERS aforeſaid of the ſaid Lords Ambaſſadors Extraordinary; And the LETTER of Lieutenant Admiral *Trump* therein mentioned, Tranſlated into Engliſh.
London, Printed by *John Field*, Printer to the Parliament of *England*. 1652.

Figure 8.2. Bluster, Confrontation, Parliamentary Inquiries, and War.[26] After Sir George Ascuye's West Indies raid aimed at enforcing the 1651 Navigation Acts (where he captured 27 Dutch merchant ships trading with Royalist Barbados) and Maarten Tromp's refusal to acede to Cromwell's demand for salute in the Narrow Seas, a small battle erupted near Dover at Goodwind Sands in May of 1652. Although Robert Blake took two Dutch ships, Tromp was able to safely escort his fleet and trade convoy home. Dutch entreaties and Parliament's inquiry (upper left) could not forestall the first Anglo-Dutch War and Parliament declared war that July. Depicted to the upper right is a sketch of the battle.[27] Remarkably the Parliamentary inquiry examines and translates three Dutch entreaties as well as testimony from Tromp; although commercial rivalry, accumulated grievances on both sides, and the threat posed to the Dutch carrying trade by the Navigation Acts made conflict virtually inevitable without unilateral concessions.

Johan de Witt, the 'Grand Pensionary' and Cromwell ended the first war in 1654 in an inconclusive draw, remedying no disputes, but agreeing secretly to bar any future member of the House of Orange to serve as Stadholder or as military leader of the States. The Dutch also

[25] Rodger, *Command*, 15, Parliament codified the "Laws of War and Ordinances of the Sea." This was to become the precursor to the Royal Navy's Articles of War.
[26] *Parliament Answers, 1652*, pg. 18.
[27] Grant, James, *British Battles on Land and Sea*, volume 1 (1873), 302.

agreed to prohibit Charles II from residing in their territory. This irritation was not forgotten by Charles II when he assumed the English crown in 1660.[28] Although inconclusive politically, the war did provide the great Dutch admiral Marteen Tromp and the English admirals Monck and Blake time to develop the new line of battle doctrine which emphasized heavily built ships, massive broadside batteries, rigid sailing discipline, and large battle fleets fighting in tandem as the arbiters of sea power.[29] Also, the English, especially under Blake, affected the first truly effective blockades of the Early Modern period over long periods of time.[30] Technological advancements, increased mariners skills, and evolving administrative and victualing operations ashore, were beginning to make enforcing national will through sea power a reality. However these new technologies, social groups, and administrative organizations required the regular expense of great deals of money, which were often beyond the scope of medieval kingdoms or small principalities. The financial burden was also wreaking havoc upon the political stability of emerging states.

Charles II inherited a financial disaster along with his crown in 1660.[31] A decade of intense warfare had resulted in an enormous naval debt and disgruntled and unpaid mariners and

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[28] Rodgers, P.G., 16-17.

[29] Herman, 185, notes the contrast between the Dutch and English rise as global naval powers, "The Dutch had turned themselves into a formidable naval power in order to keep their overseas trade. The English did the opposite. It was their rise as a naval power, driven by the discipline of the Mew Model Army and militant Protestantism that allowed them to become a major trading nation."

[30] Rodger, *Command*, 3-4, 18, Blake and Deane first blockaded Royalist forces under Prince Rupert in Ireland at Kinsale making possible Cromwell's crossing and conquest, and Blake followed Rupert's fleet to Lisbon in 1650, effectively blockading the neutral port and even seizing part of the Portuguese treasure fleet of that year arriving at the Tagus River from Brazil. In 1653 Blake and later Monck led the successful blockade of the Dutch coast which culminated in Monck's defeat of Tromp at Texel [the 1653 Battle of Scheveningen was fought near Texel, not to be confused with de Ruyter's victory over the French and English in 1673, also called the Battle of Kijkduin].

[31] Rodgers, P.G., 28, notes that "during the Commonwealth more than half the national revenue was spent on the Navy." Despite these outlays, in 1660 arrears of pay due to sailors was £400,000 (some men had gone unpaid for four years), and the naval debt was £1,284,452. He adds, 40, that by January 1660, "the government was essentially bankrupt, and the Navy needed £2,157,883 to pay off its debts and fit out a Summer Guard."

Herman, 185, notes the upside of this debt, since "Charles II inherited more than 120 warships from his predecessors. Blake and Monck had made England a major player on the world stage." His supporting analysis of the correlation between tonnage of warships built in the period and the subsequent increases in maritime trade despite the depredations of Dunkirker and French pirates is persuasive.

naval suppliers. However, The Dutch under de Witt, rebuilt their economy quickly and started a large ship building program centered on large English style battleships. These ships had a shallower draft than their English counterparts, but as Rodger notes, this was more of a political choice than one forced upon the Dutch by geography. The entry to Amsterdam's harbor was indeed shallow, and de Witt insisted that all the navies of the States build their ships with an ability to clear Pampus bar on the River IJ, despite the objections of his other admirals.[32] This political decision would have consequence as the wars ran onward, as shallower draft necessitated somewhat smaller ships. However, the Dutch building program was impressive and its significance was not fully appreciated by English intelligence or policy makers.

When the unresolved economic enmities of the first conflict seemed to indicate that war was inevitable, Parliament granted Charles II the unprecedented sum of £2.5 million.[33] His reconstituted Navy Board refit his fleet and under the command of the reinstated Lord Admiral of England, James Duke of York, mustered 100 ships and delivered the Dutch a significant defeat at the battle of Lowestoft in June of 1665. The English fleet was well organized and benefited from predetermined signals to control its line. When the Dutch commander Admiral Odam was killed, the rival admirals of the seven Dutch admiralties involved fought over priority. Unfortunately for the English, James did not follow up on his victory and de Ruyter returned from his Atlantic cruise in time to refit the fleet and instill line of battle discipline and an innovative signaling protocol upon it. In the grueling Four Days Battle the following year, de

[32] Rodgers, P.G., 27 and 41, notes on the eve of the second war in early 1665, the Dutch had a substantial fleet of 100 ships "mounting 4,800 guns, and with crews totaling 21,000 men."

Rodger, *Command*, 67, notes "de Witt was a strong supporter of the navy, and at the end of the previous war with England he had forced through measures which created the first major Dutch fleet of purpose-built warships – a development of which the English were not sufficiently aware."

Konstam, Angus, *Warships of the Anglo-Dutch Wars 1652-74*, 19-23, notes that this draft requirement of fifteen feet was the equivalent draft of an English Fourth Rate ship. In consequence, the Dutch ships had flatter bottoms and broader beams than their English counterparts. This design feature had the advantage of making them more stable gun platforms, but at the expense of maneuverability.

[33] Rodger, *Command*, 77.

Ruyter and the Dutch soundly defeated parts of the divided English fleet in succession in what has been termed the greatest battle of the Age of Sail.

The English, once again, short of funds, and now confronted by both France and Denmark, decided not to fit out a battle fleet in 1667. Charles was relying instead upon peace negotiations and the secret help of Louis XIV to achieve a respectable settlement.[34] De Witt and de Ruyter's daring raid on the fleet at Chatham dockyard on the Medway, their capture of the *Royal Charles*, flagship of the fleet, and their effective blockade of the Thames estuary, rendered those hopes politically futile. That this last defeat was in part attributable to the lamentable, if not understandable, performance of unpaid English sailors and dockyard workers, underscores the breakdown in the administrative and financial capabilities of seventeenth century England.[35] In the words of Samuel Pepys, the Clerk of Acts, or Secretary of the Navy Board, "Thus in all things, in wisdom, courage, force, knowledge of our own streams, and success, the Dutch have the best of us, and do end the war with victory on their side."[36]

When Charles II again declared war on the Dutch in March of 1672 he did so with the aid of Louis XIV. The Dutch Republican faction had fallen with the brutal public murders of the de Witt brothers and the Royalist faction supporting the House of Orange was ascendant. The young Prince William III spurred the overtures of his uncles Charles II and James, and rather pursued *La cause commune*, encouraging European unity against the ambitions of Louis XIV.[37] In England the control of foreign wars was shifting back toward Parliament as the King's royal revenue was entirely inadequate for maintaining a large battle fleet. And once again, the

[34] Rodgers, P.G., 53.
[35] Ibid, 14, cites Pepys quotations of the wives in explaining the cowardly and in some instances treasonous behavior of the sailors and workers at Chatham, "This comes of your not paying our husbands."

Rodger, *Command*, 79, notes that Dutch spent the equivalent of £11 million on the war which was more than twice the English expenditures.
[36] Pepys, Samuel, *The Diary of Samuel Pepys, Esq., F.R.S., from 1659 to 1669*, volume 3, 422.
[37] Barone, 45. William III was also the son-in-law of James II, having married James's daughter and William's first cousin Mary Stewart.

decisions to build large ships for the second Dutch war had all but halted the Commonwealth frigate building program of escort cruisers and the nation's exposed merchant shipping class bore the brunt of the war.

The Dutch survived the combined assault on land and sea from France and England but only after William was forced to flood a great deal of his occupied country and de Ruyter's victory over the larger combined allied fleet off the Texel in August of 1673.[38] Once again, out of money and short on triumphs, Charles II had to sue for peace. His need to seek Parliament's aid ended his policies of religious tolerance, French alliance, and any other initiatives that contravened the will of Parliament.[39] Once again, however, the English drew lessons from both their draws and defeats. Following this last war the institution of the navy had accomplished several transformative steps. Its administrators had established a reliable and consistent supply system for maintaining a fleet out of home waters in the Mediterranean, they rebalanced their naval forces across a wide variety of ships, and they finally institutionalized procedures for reliable merchant convoy escort.[40] But the overriding lesson of the Dutch wars, for both the Commonwealth and Charles II, was that naval war could not be fought on the cheap. The Dutch survived against far larger self-sufficient neighbors, with exposed sea lines of communications, because they had the financial wherewithal to outspend their antagonists and support that spending with a vibrant modernizing economic system privileging capital over land. The English would emulate these proto-modern financial innovations to enhance their sea power.

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[38] Dull, 22, notes that de Ruyter was "the greatest admiral of the century." Not only did he consistently defeat or check the numerically superior French and English fleets, but he succeeded in poisoning relations between England and France, due the former's withdrawal at Solebay and Texel and the latter's accusations of allied cowardice.

[39] Rodger, *Command,* 87.

[40] Konstam, *Warships of the Anglo-Dutch Wars,* 18, "This, then, was the real legacy of the Anglo-Dutch Wars – a Royal Naval battle fleet that consisted of well-rounded and well-built ships, whose designs were based on the hard-won experience of three major naval conflicts."

Rodger, *Command,* 91, notes that the routinization of convoy escort was largely a product of their Mediterranean operations in the 1680s.

Financial Innovations and the Creation of Modern Finance

"The sinews of war are infinite money"
– Marcus Tullius Cicero

The size and complexity of early modern warships increased throughout the sixteenth and seventeenth century, as did the cost of building, gunning, provisioning, manning, and maintaining them. The outsized ambitions of European princes produced larger ships and grander fleets. The cost of maintaining these ships and fleets quickly became exorbitant. As the seventeenth century progressed, only the wealthiest states, or those wholly committed to the sea, could afford to maintain fleets for long periods of time.[41] The past medieval practice of requisitioning merchantmen for short single season campaigns was no longer feasible. The technological complexity of purpose-built warships and the training required to man and command them, coupled with the onshore logistics infrastructure required to provision and maintain them, dictated the necessity of standing navies. And standing navies required a large steady stream of funding in both peacetime and war. National maritime commitment required long-term public support and a dedicated funding source. It was in the protestant north, and specifically in Restoration England, that this commitment to a permanent navy was first realized.

[41] Small nations like Scotland under a nautically minded ambitious king could launch grand building programs like the one that produced the Great Michael, but then be forced by financial circumstance to sell off their assets at a fraction of their cost. Rich nations like France (under Richelieu or Colbert) and Spain (post-Armada) sporadically built great navies only to let them whither as the passions of the moment faded or spending priorities or shaky finances faltered.

Dull, 13, notes that "by 1670 the French navy had more tons of ships than the navies of either England or the Netherlands." However,

Rodger, *Command*, 142, observes that the navy built by Colbert under Louis XIV in twenty years, although impressive in numbers, was little more than "an accountant's navy, a bureaucrat's dream whose function was to obey regulations and balance the books." He notes that "more than twice as much money was spent on shipbuilding as on the naval yards, which were quite inadequate to maintain the ships." They lacked adequate dry docks and an effective ordnance industry among other technical organizations. Modern naval war required logistical support infrastructure as the English and Dutch had learned and committed to over long periods of time. Neither that infrastructure nor a robust mariner community could be improvised, even under the auspices of the most effective administrators and devoted monarchs, in just two decades.

Herman, 217-218, adds that the French navy of Colbert was highly drilled in the manouvers of the naval theorist and mathematician La Hoste, that its excellent ships could sail within six points of the wind as opposed the English seven, but that it was a "by the book" institution, that lacked adaptability of its English foe in battle.

As medieval Europe evolved into modernity there existed a struggle between the traditional privileges of the monarch: foreign policy and waging war; and those of medieval parliaments: raising or more accurately, limiting taxes. The French under the Bourbons moved in the direction of absolute monarchy and a centralized state – reconciling the conflict by eliminating parliamentary power. The English maintained the right of Parliament to raise taxes and over the seventeenth century this power of the purse became so powerful as to intrude upon the monarchal privileges in setting national strategy, conducting foreign policy, and waging war. The Stewarts did not relinquish this power easily and the English required a civil war, the beheading of a king, a failed Republic, a military dictatorship, a restored monarchy, and a Dutch invasion, to finally resolve the issue of preeminence. The funding and proper use of the Navy, a central institution in the seventeenth century national English mythology, was of central importance in this struggle.

It was Charles I that first seemed to resolve the struggle by finding an independent funding source for a standing navy. His naval objective – state power projection through the dominance in the fleet of large capital ships – conflicted with parliamentary interests of the London merchant community and West Country privateers, who had the respective objectives of protecting national coastal shipping and expanding global trade on the one hand, and fighting European Catholic universalism by attacking Spanish Iberian shipping and colonies on the other. They envisioned a navy of raiding cruisers and merchant escorts. Parliament would not raise tax levies to buy grand warships like the *Sovereign of the Seas* (1637), if their livelihood was being captured regularly by Dunkirker pirates or Barbary corsairs. But, Charles believed that he had discovered his financial vehicle of naval independence in 1634 in the form of Ship Money.[42]

[42] Rodger, *Safeguard*, 381.

In addition to the regular assignment of import duties collected by the crown and allocated to navy, Charles assessed each of the maritime counties a levy of ships (like the Saxon *scipfyrd*) with the intent of receiving cash reimbursements instead.[43] The rationale for the Ship Money was explicitly tied to the notion of sovereignty of the seas and was expounded upon in John Seldon's *Mare Clausum*. Each summer Charles would assemble a Ship Money fleet of large warships to patrol the Channel and assert English sovereignty over those waters. These cruises did much to enhance Charles's international prestige but little to stop the depredations of piracy or raids upon the fishing fleets.

The Long Parliament outlawed Ship Money in 1640 and the victorious Parliament reoriented the navy toward trade and coastal defense. But they also provided tax revenue for a permanent Navy. As we have noted, as the Commonwealth's ambitions grew, so did its naval outlays. Despite the ultimate financial collapse of the Commonwealth's finances, Rodger notes that treasury and the Navy Commission started issuing notes "payable 'in course'", or in effect T-Bills.[44] This innovation – borrowing against specific future dedicated tax revenues – enabled the emergency spending needed to continue the government's expensive war efforts without the need to appeal to Parliament for special taxation. However, the long-term accumulation of debt, and the regular practice of paying short-term operational expenses by deferring payment of wages and payments to suppliers, eventually dispirited the Navy and rendered successive governments insolvent. In 1681, Charles II even accepted a direct annual stipend from Louis XIV of 2 million livres (almost £150,000), which when combined with his royal income of

[43] Rodger, *Safeguard*, 381-382, notes that London actually furnished a few ships, but overall the levy netted almost £80,000 annually. It was treated as a payment in lieu of service paid directly to the Treasurer of the Navy instead of into the Exchequer.

[44] Rodger, *Command*, 41, adds that although this "was nothing like a permanent national debt, the Commonwealth was the first moderately credit worthy English government in modern times." 'In course' meant payed back in order of issue, reckoned by numerical sequence.

roughly £1 million, could support his government in peacetime without any input from Parliament.[45] However, peacetime in the seventeenth century was far more often the exception than the norm. The English nation eventually acknowledged "that only permanent taxation could support permanent fleets."[46] However, permanent taxation in sufficient volume to equip fleets, to maintain domestic comity, and to be economically feasible, required a vibrant financial sector and a population committed to the maritime trade ethos. To accomplish this, the English would need to emulate their Dutch rival.

Prior to the Anglo-Dutch Wars, the Dutch viewed England as an economic frontier offering opportunity in a less competitive environment than at home. Seventeenth century England imported Dutch expertise in land reclamation, canal technology, mining, printing, textile manufacturing, and finance.[47] Although the cross-border movement of technical expertise was critical in the development of England's economy and maritime interests, London's ascension as global leader can be traced to mastering Dutch financial practice. Michael Barone notes that

> "Around the beginning of the seventeenth century the Dutch established the Bank of Amsterdam – modeled on the central banks that made Venice and Florence continental powers – the Amsterdam Bourse, commodities markets, a market in maritime insurance, and a low-interest national debt. All of these made Amsterdam the world's premier finance center." [48]

The Amsterdam Bourse was the stock exchange created in 1602 by the VOC to trade its company stock certificates and company bonds. The Amsterdam stock market has often been

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[45] Barone, 78, Louis XIV initially offered 1.5 million livres (£110,000) in exchange for England's abandonment of its Spanish alliance and an agreement to join no alliances against France. Charles II held out for 2 million livres.

Rodger, *Command*, 81, notes that Louis XIV's income at the time was 100 million livre (£7.5 million) or over seven times that of Charles II.

[46] Rodger, *Command*, 41.

[47] Rodgers, P.G., 7-10.

[48] Barone, 30, citing Haley, *The Dutch in the Seventeenth Century*, 38-43, notes that from 1655 the Dutch state could borrow at only four percent; far less than its Catholic or Protestant competitors.

referred to as the world's first modern market. Fernand Braudel notes that like modern banking, it is more accurate to locate its origin to the Mediterranean, noting that

> "It is not quite accurate to call [Amsterdam] the first stock market, as people often do. … All evidence points to the Mediterranean as the cradle of the stock market. But what was new in Amsterdam was the volume, the fluidity of the market and publicity it received, and the speculative freedom of transactions."[49]

For our purposes it is important to note that the Amsterdam market was able to produce the enormous liquidity required for maritime projects and global trade. It was modern in the sense that it broadened and depersonalized the investor base and made grandiose projects possible without the direction of nation states. The institution was also quickly emulated by the English.

We addressed the critical impact that joint stock companies had on the early development of global trade in Chapter 5, with reference to both the Dutch VOC and WIC, and the English East India Company. And even though the public trading of joint stock company shares was vigorously initiated in Amsterdam, it is important to reiterate that the English were early pioneers themselves in the arena of diversifying risk and pooling of resources for maritime projects. When assessing the impact of the early Muscovy Company from the middle of the sixteenth century, Waters notes that

> "… the commercial organization … the joint-stock company, created to finance the trade that arose from the [Artic] discoveries, proved so sound that it was adopted with equal success as a means of financing later trading, colonizing, and raiding ventures otherwise quite beyond the means of individual merchants or captains or even the Government."[50]

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[49] Braudel, Fernand, *Civilization and Capitalism 15th–18th Century: The Wheels of Commerce*. He cites a number of examples: "State loan stocks had been negotiable at a very early date in Venice, in Florence before 1328, and in Genoa, where there was an active market in the *luoghi* and *paghe* of Casa di San Giorgio, not to mention the *Kuxen* shares in the German mines which were quoted as early as the fifteenth century at the Leipzig fairs, the Spanish *juros*, the French *rentes sur l'Hotel de Ville* (municipal stocks) (1522) or the stock market in the Hanseatic towns from the fifteenth century. The statutes of Verona in 1318 confirm the existence of the settlement or forward market ... In 1428, the jurist Bartolomeo de Bosco protested against the sale of forward *loca* in Genoa."
[50] Waters, 88.

This innovation produced investor profit and potential wealth for taxation, but in order to finance permanent navies of the magnitude demanded by seventeenth century geopolitics, we must look at the Bank of Amsterdam and its intellectual offspring, the Bank of England (BOE). But before we can address the BOE, we must first make note of the demise of the Stewarts, the Dutch capture of the English monarchy, and the rise of Parliament.

Upon the ascension of James II in February 1685, Parliament at first supported the new king. They voted for him the same lifetime revenues which they had granted Charles (customs, excise, and the like) and even voted additional revenues to discharge Charles's debts and refurbish the fleet.[51] However this initial comity did not last. James thwarted a coup attempt by Charles's bastard son the Duke of Monmouth in his first year, but his Catholic tolerance and nullification of the Test Acts, his proroguing and eventual dissolution of Parliament in 1686 and 1687 respectively, and his scheme to pack a more conciliatory Catholic friendly Parliament pushed the more ardent English Protestants to the breaking point.[52] Religion aside, James II was attempting to move England toward the absolute monarchy model of Louis XIV in a nation where Parliamentary forces had recently cut the head off one monarch (his father) and which had used the purse strings to keep another (his brother) on a very short leash.[53] We will look at the maritime aspects of William's invasion below, but at this point we will examine some of the Dutch innovations which flowed in the wake of the Prince of Orange's entrance into his father-in-law's conflicted realm.

[51] Barone, 89, notes that initially these revenues were set at £1.2 million, but in Charles's reign receipts initially did not hit expectations. However increased trade produced revenues of £1.3 million in 1684 rising to £1.6 million by 1687. These revenues enabled the monarchs to run their governments in peacetime without Parliamentary levies.

[52] Ibid, 104, cites an Anglican minister in exile's pamphlet exclamation "that popery and poverty go together, because popery goes with tyranny and tyranny is econocidal [sic]." The author, 109, cites J.R. Jones, "the campaign to pack Parliament was easily the most important [factor] in provoking [The Glorious] Revolution."

[53] Israel, Jonathan I., *The Anglo-Dutch Moment: Essays on the Glorious Revolution and its World Impact*, 3, notes that William III's invasion spurred the belief "that the country had been definitely saved from the style of royal government practiced by James II – which contemporaries called 'absolute power'."

Discontent after the ascension of William III and Mary II among the Tory gentry, Anglicans, and commoners suffering from increased taxes manifested itself in a xenophobic rejection of the "influx into England of a much-noticed wave of fortune-seeking Dutchmen, Huguenots, and Jews."[54] More likely, the discontent was fueled by William's wars of consolidation within the British Isles and his insistence that England participate in his anti-French crusade on the continent. William III was first and foremost the Stadtholder of the Dutch Republic and its existential struggle against the imperial ambitions of Louis XIV was his primary concern. But William's wars were expensive and borrowing was necessary. Due to default risks, Charles II and James II faced leverage costs of ten to fifteen percent. Dutch creditworthiness was superior and they were able to borrow from the Bank of Amsterdam at four to six percent. After considerable wrangling, Parliament charted the BOE in 1694. Barone notes, that "in effect the Bank of England was given a monopoly of government borrowing, and investors ('subscribers') were guaranteed 8 percent interest."[55] The symbiosis between a representative Parliament with taxing authority and the BOE providing low cost government debt gave England an enormous advantage over its wealthier and larger continental rivals over the next several centuries.[56] In addition William III, as Stadtholder of the Dutch Republic and not a king, was used to negotiating within a fractious political milieu. Upon his ascension he invited Parliament to review and audit his ministers' accounts.[57] The combination of public accountability and stable credit from the BOE and Parliamentary guarantees created a 'Financial

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[54] Israel, 43.
[55] Barone, 221-223. The Bank of Amsterdam was chartered in 1609.
[56] Ibid, 224.
Dull, 34, notes that the BOE was privately financed and established the Royal Navy's first "efficient and reliable source of loans."
[57] Barone, 221, cites Tony Claydon's observation that William "should therefore receive much of the credit for establishing the modern annual cycle of parliamentary budget setting, and financial scrutiny," as his invitation led Parliament to establish a nine-member Commission of Public Accounts in January 1691.

Revolution' in the 1690s which greatly enhanced both state and private revenue.[58] Once again these modernizing developments were spurred by the maritime trade class. As Barone notes

> "It was the merchants of London, working with members of Parliament, who devised the financial expedients needed to finance William's war with France. The creation of the national debt in 1693, regularized later by the sinking fund, and of the Bank of England in 1694 gave London and England financial institutions that closely resembled those of Amsterdam and the Dutch Republic."[59]

The Parliament in part represented the merchant class and that class expanded its influence as the maritime trade project expanded. They also became active participants in England's financial modernization; the London merchants John Houblon and Michael Godfrey were selected as the first governor and deputy governor of BOE respectively in 1694.[60] The maritime interests who guided the decisions of Queen Elizabeth and fought her wars were now controlling and funding the English state through complex proto-modern institutions. The inspiration for many of these institutions was undoubtedly Dutch.

Another pioneering venture in risk pooling adopted in part from Dutch practice concerned maritime insurance. Lloyd's of London, the iconic and in its heyday, the world's largest insurance market, unambiguously recognizes its maritime roots,

> "In the 17th century, London's importance as a trade centre led to an increasing demand for ship and cargo insurance. Edward Lloyd's coffee house became recognized as the place for obtaining marine insurance and this is where the Lloyd's that we know today began."[61]

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[58] Israel, 23, notes that this revolution "made a considerable contribution to the emergence of England as a major European power." Royal annual revenues jumped from less than £2 million in the 1680s to £5 to £6 million from 1689 to 1702.

[59] Barone, 235, adds a note from P.G.M. Dickerson who stated, "the newly aggressive and dynamic English monarchy became, in effect, an eighteenth century version of the seventeenth century Dutch Republic, with its powerful fleet, numerous army, extended credit, and sophisticated indirect taxation."

Herman, 221, acknowledges that the national bank and a national lottery derived from Dutch example, but that the 'navy bills' paying 10 percent interest and secured by the government and traded by speculators as government bonds, also drove the 'Financial Revolution.'

[60] Barone, 79.

[61] Lloyds.com, https://www.lloyds.com/lloyds/about-us/history.

Edward Lloyd's coffee house first appeared in print records in 1688. Its first business was to be the coffee house of choice for London's sailing merchants and investors. In order to win this distinction it had to serve as an information clearing house about the nascent industry in order to attract the London merchants involved in long-distance trade. It also brought together marine insurance underwriters and prospective clients. Although various practices of mitigating maritime risk date back to antiquity, and the late Elizabethan Parliament had passed "An Act Concerning Matters of Assurances Amongst Merchants" in 1601, the emergence of vibrant insurance markets properly belong to the late seventeenth century.[62] Unlike the heavily regulated state protected trade of the Iberian south, the long-distance trade of the Dutch and the evolving English competition was often private, and as we have seen in the case of the English, beyond the protection of state navies. The inherent risks of storm and sea, primitive navigation and inaccurate instruments, wooden boats, intermittent propulsion, poor nutrition and tropical disease, and faulty or blank charts, when combined with the depredations of corsairs and state sponsored pirates, posed serious impediments to anyone trying to seek his fortune from the sea. Almost as varied as the risks, were plans to mitigate them – at least for the investors standing behind these voyages.

Sabine Go, in her analysis of Early Modern Dutch maritime insurance, notes that the earliest method used to mitigate risk was for merchants to accompany each voyage in order to at

[62] Berketis, Nicholas G., "The History of Marine Insurance – Its Origin," 2-12, briefly sketches the long history of marine insurance, "the oldest form of indemnity of which there is any record." Although covering the various forms of maritime law and bottomry bonds where a ship or its keel, was used as collateral for an investment and risk protection to Ancient Rhodes, Greece, and Rome, the author posits that the banished twelfth century French Jewish community resettling in Lombardy deserves the honor of reviving bottomry bonds during this exodus. He credits the Genoese of the mid-fourteenth century for separating maritime insurance from the investment/collateral elements inherent in this bonding mechanism. The Hanseatic League had an insurance center in Bruges as early 1432 and established a London outpost on Lombard Street. The Elizabethan Assurances Act did establish a Court of Insurance, but it was mostly disregarded by merchants and common law courts.

least control theft and fraud reducing at least one of the many risks inherent in trade.[63] The Dutch made extensive use diversifying ownership between numerous merchants and ship owners, often selling parts of the ship or *partenrederij*.[64] Of course arming ships to protect against human threats was common, especially since most early modern traders were also piratical opportunists themselves. In addition, travelling together for mutual support, as the Venetians pioneered in the Mediterranean with their *muda* system in the thirteenth century or as we have observed with the Spanish *flota*, could again mitigate human risks, but even the armed galleys of the *Signoria* or the King's galleons could not eradicate the dangers of storms and hidden reefs.[65] To help defray these risks the Dutch made wide use of bottomry loans which used the ship and cargo as collateral, but only had to be paid, with interest, upon arrival at the port of destination. This was not pure insurance since these loans combined for the underwriter an investment return, a collateralized ship and/or cargo, and disaster risk transfer from the merchant. Go notes that Dutch bottomry premiums or *opgelt*, could range from thirty to seventy percent of the loan value, and so were not very attractive for merchants.[66] As shipping expanded, merchants devised and demanded more appealing options.

Groups of Dutch merchants formed Protection and Indemnity Clubs creating a mutual insurance were the group collectively bore the risks each member, without having an investment

[63] Go, Sabine, *Marine Insurance in the Netherlands 1600-1870, A comparative institutional approach*, 23, adds that travelling with their product could protect them from *risicum gentium*, but of course could do little for *riscium maris*.
[64] Ibid, 23-24, notes that this had the added benefit of spreading ship ownership widely among the merchant class, and although quarter, sixteenth, or thirty-second shares were most common, shares could be as small as 1/256th, which opened this investment vehicle to a far greater part of the population than in other European states.
[65] Crowley, *City of Fortune*, 287, notes that "The muda system, where merchant galleys travelled in convoy, was introduced to ensure a level of mutual defense."
[66] Go, 24.

stake in each particular transaction.[67] Lastly the Dutch developed a direct insurance were merchants could purchase a predetermined disaster coverage from an underwriter for a simple premium which did not obligate him to share his profits or protect other ventures. However, combining merchants with underwriters and calculating realistic risk premiums requires information and a space for the parties to meet, negotiate, and compete. As the later rise of capitalist economies would so amply demonstrate, the most effective mechanism for this exchange was a market. This is what the Dutch set up in Amsterdam and Rotterdam, among other major ports, and what Lloyd emulated in his coffee house. This maritime inspired mechanism for gauging and mitigating risk has had profound implications for the evolving societies of the Early Modern period. Risk was no longer something that had to be passively endured. However, the actual invasion that brought the Dutch Stadt Holder to the English throne was anything but risk free.

Intelligence Failures, Large Scale Propaganda, and the Dutch Armada

Even though William meticulously assembled the largest fleet ever to invade England and embarked upon it a well provisioned and seasoned Dutch army, the Government functionaries of James II were either caught unaware or in a number of notable cases, were complicit. The remarkable Dutch administrative achievement illustrates how the modernizing bureaucracies of the northern Protestant nations had gained proficiency in assembling the enormous amounts of men, materiel, stores, and money for Early Modern naval warfare. As Roger notes, "the whole force was at least double the size of the Spanish Armada of a century

[67] Go, 24, 36, traces the emergence of these mutual insurance clubs to the province of Groningen. By 1605, the Guild of Great Skippers (*Groat Schipper Gilde*) had decreed that their members would contribute a set percentage of each cargo into a fund created for covering lost ships (half) and for poor relief (half).

before, assembled in little more than a tenth of the time."[68] As salient, the expedition did not bankrupt the aggressive power. But perhaps more impressive, and again in contrast to Phillip's effort, was the ability of William and his ministers to keep James largely unaware until the invasion was a *fait accompli*. By choosing the dangerous autumn sailing season for his invasion, William had convinced the prior Lord Admiral and current sovereign that France must be the target of the Dutch fleet.[69] This was not a totally unreasonable supposition as William's overriding motivation was opposition to French hegemony.[70]

Sailing in late autumn was indeed perilous. The invasion flotilla set sail on October 19, 1688, but was blown back into port. When it sailed again on November 1st, the winds were driving from the east and William sailed north. Very few people in William's circle had knowledge of his intended landing. When he turned down-Channel, the English fleet was weather-bound and unable to immediately intercept him. By the time they were able to pursue, William was safely landed in Torbay, Devonshire. A Protestant wind was again blowing, much

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[68] Rodger, *Command*, 137. He also notes that William III was fortunate in his continental enemy; Louis XIV's brutal invasion of the Palatinate and subsequent seizure of Dutch merchant shipping in French ports rallied the Republicans behind the Prince of Orange. Of the 'Immortal Seven,' he notes that although all were of "some public standing," Admiral Herbert was the significant representative from the Navy, who later became commander-in-chief of the Dutch invasion fleet.

Herman, 209-210, adds that Herbert commanded the Stuart navy's anti-piracy patrols from Tangiers, the only post where captains of the time could gain combat experience. He built up a loyal following among his officers (the 'Tangerines') and their success against the corsairs earned him the promotion to Admiral of the Fleet in 1683. James II dismissed him in 1687 for refusing to support his Catholic Indulgence on principle despite Pepys's observation that "of all the worst men living, Herbert is the only man that I do not know to have any one virtue to compound for all his vices."

Barone, 137, adds that Herbert, disguised as common sailor conveyed the letter of June 30, 1688, from the 'Immortal Seven' to William pledging their support if William invaded in order to stop James from packing Parliament. He concurs, 136, that these seven were "not necessarily the most prominent men in England." They included Admiral Russell, the Earl of Danby, the Earl of Shrewsbury, the Earl of Danby, The Viscount Lumley, The Bishop of London (Henry Compton), and Henry Sidney. He adds, 139, that the letter was encoded in a cipher, unlike John Churchill's (later the Duke of Marlboro) letter of invitation.

[69] Rodger, Command, 138, notes "Both James II and Louis XIV had their attention elsewhere and were badly served with intelligence on Dutch preparations. It was not until late August that James II began to take the possibility of Dutch intervention seriously and ordered the main fleet to mobilize."

[70] Barone, 119, notes that throughout 1686 and 1687 English and Scottish Protestants made many pilgrimages beseeching William's intervention, all of which he refused; "William's prime goal was to oppose the power of France."

to the disservice of England's Catholic sympathizing monarch.[71] However William's risky choice of sailing season and personal discipline in masking his intent from courtiers, were not the only keys to his successful intelligence and concealment operation.

Both rulers had spy networks, often as was customary, run out of their respective embassies abroad. Sir George Downing (of 10 Downing Street notoriety) had run an elaborate espionage operation while serving as Charles II's provocative ambassador at The Hague leading up to the second Anglo-Dutch War, although he and his successors missed the significance of de Witt's naval ship building program.[72] William had spies in both England and Scotland.[73] However, it was from alarmed English Protestants from which William got most of his intelligence about James's prospects in the upcoming election, his staffing of the Army with Catholic officers, and even his decision to outfit thirty-five more ships at the end of August 1688.[74] Although not a large group, these men were fighting to preserve the discriminatory Test Acts (which they considered essential in protecting Protestantism from Catholic usurpation) and the encroachment of creeping absolute monarchy shielded under the guise of a puppet Parliament, and the threat of a Catholic dynasty engendered by the recent and contested birth of

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[71] Herman, 214-215, notes that "William had intended to land in Yorkshire, far from James's army assembled on the southern coast," but that the wind changed his plans. This same wind enabled him to speed down Channel and keep the English fleet in the Thames estuary under Dartmouth trapped. When Dartmouth was able to persue and was insight of the Dutch fleet, another wind change both allowed William's forces to land and drove Dartmouth back up the Channel. The Calvinist William accepted the changes as confirmation of both predestination and God's will.

[72] Rodgers, P.G., 21-22, notes that Downing was seen by contemporaries as a caustic character. He had been a Cromwell supporter and served as ambassador from 1657-1660. He was pardoned and knighted by Charles II and sent back in 1661. He claimed, according to Pepys, to have often "had the keys taken out of de Witt's pocket when he was a-bed," in order to purloin and read his papers and return them unnoticed.

[73] Barone, 90, notes that William's agent in Scotland, William Carstares provided information to him about both Argyll's manifesto and probably the Duke of Monmouth's insurrection in James II's coronation year. He adds that, 120, Count Zuylestein transferred his information to William using invisible ink and secret couriers.

[74] Herman, 210, argues that James II's decision to keep his standing army of 40,000 men, with its large number of Catholic officers, which was raised to suppress the Monmouth rebellion, was in fact the unacceptable act that goaded most protestant Englishmen. With memories of Cromwell still fresh, they feared this army would be used to crush their religion, just as Louis XIV had used his army in the 1680s to destroy the Huguenots.

James II's son. And it was this sentiment, sympathized with if not acted upon by a much larger part of the population, to which William appealed.

Once again, as was done by his ancestor at the outbreak of the Eighty Year's War, a Prince of Orange weaponized the printed pamphlet.   William had printed in secret 60,000 copies of his *The Declaration of His Highness William Henry, by the Grace of God, Prince of Orange, etc., of the reasons inducing him to appear in arms in the Kingdom of England, and for preserving the Protestant religion, and for restoring the laws and liberties of England, Scotland, and Ireland* in English in The Hague, Amsterdam, and Rotterdam.[75] In late autumn 1688, his agents flooded England with his manifesto.[76] James's government unable to suppress it had to reprint it and refute its main points. Although the English were well practiced at using pamphlets to drum up public sentiment, the scale of this endeavor was new. According to Jonathan Israel, "the Prince of Orange's Declaration was one of the greatest and most decisive propaganda coups of early modern times."[77] Within weeks of William's landing and slow march on London, James II fled the capital for France. His subsequent defeat in Ireland in the summer of 1690 at the Battle of Boyne to William secured the latter's power and the firm, but watchful allegiance of Parliament.

The Glorious Revolution resolved with finality the question of monarchal or Parliamentary supremacy in Great Britain, with the latter's ascendance.[78] Although William's

[75] Israel, 13, notes that the *Declaration* was not just the most widely circulated, but the most influential political document of the English Revolution of 1688-9. He adds that it was written by the Pensionary of the States of Holland, Casper Fagel.

Barone, 148, notes the Dutch were masters of the political pamphlet, "the most persuasive mass medium of the day." The print run dwarfed major runs of the day of 2,000.

[76] Israel, 15, notes one of the most effective distributers was the Spanish ambassador in London.

[77] Ibid, 14.

[78] Ibid, 10, notes that "the Revolution did make Parliament supreme: and it did transform England into a religiously and intellectually pluralistic society." Despite revisionist critiques of the Whig view, this Revolution of 1688 "was the crucial turning-point in England's constitutional development." It was the point England rejected absolute monarchy and it shortly after Denmark and Sweden chose the alternative path.

wars of consolidation in the British Isles, and more importantly, his continental wars against France would consume enormous resources and connect England to European power politics in ways unsettling to most Englishmen, the advocates of Parliamentary monarchy and Protestant succession were willing to grant William these expenses and commitments to secure their goals. Parliament received their Declaration of Rights and Hanoverian succession and William and his successors checked Louis XIV and preserved Dutch independence.[79]

The second half of the seventeenth century was more than just politically tumultuous for England. The English people settled their religious and constitutional direction, but they also morphed their embrace of the sea for security and prosperity into an instrument of global power and mercantile expansion.[80] They emulated innovative Dutch financial institutions established for maritime trade and furthered their development and modernization to fund an increasingly expensive and complex navy. However, their increased financial and maritime acumen could not save them from the one of world's first great financial crashes. We have looked at the beneficial aspects of Dutch financial devices which the English incorporated, but we will briefly jump forward into the beginning of the eighteenth century to examine its negative side.

Barone, 207, notes that after crowning William and Mary, and agreeing to fund William's European war, Parliament only voted three years of custom duties to the new monarchs – unlike the lifetime grants made to the Stuart kings. "This was an English Parliament determined to keep its Dutch king on a short leash."

[79] Barone, 220, notes that government income quadrupled from £2 million in 1688 to a peak of £8 million in 1696. He adds that the number of government employees likewise tripled from the rule of James II to William III from 4,000 to 12,000. All this growth was supported by Parliamentary taxes and borrowing.

Israel, 22-23, observes that upon entering the Nine Years War in 1689, "England was transformed from being one of the most lightly taxed countries in Europe to being the second most heavily taxed after the Dutch Republic." Royal annual revenues jumped from less than £2 million prior to 1689 to £5-6 million from 1689 to 1702. He adds, 31, "The Glorious Revolution created a real balance of power in Europe … [and] replaced French dominance with general deadlock."

Barone, 193, observes that Parliament's Declaration, unlike the U.S. Constitution and later passed as a statute as a Bill of Rights in December 1689 and given royal approval, was not permanent and was "subject to repeal by a subsequent Parliament."

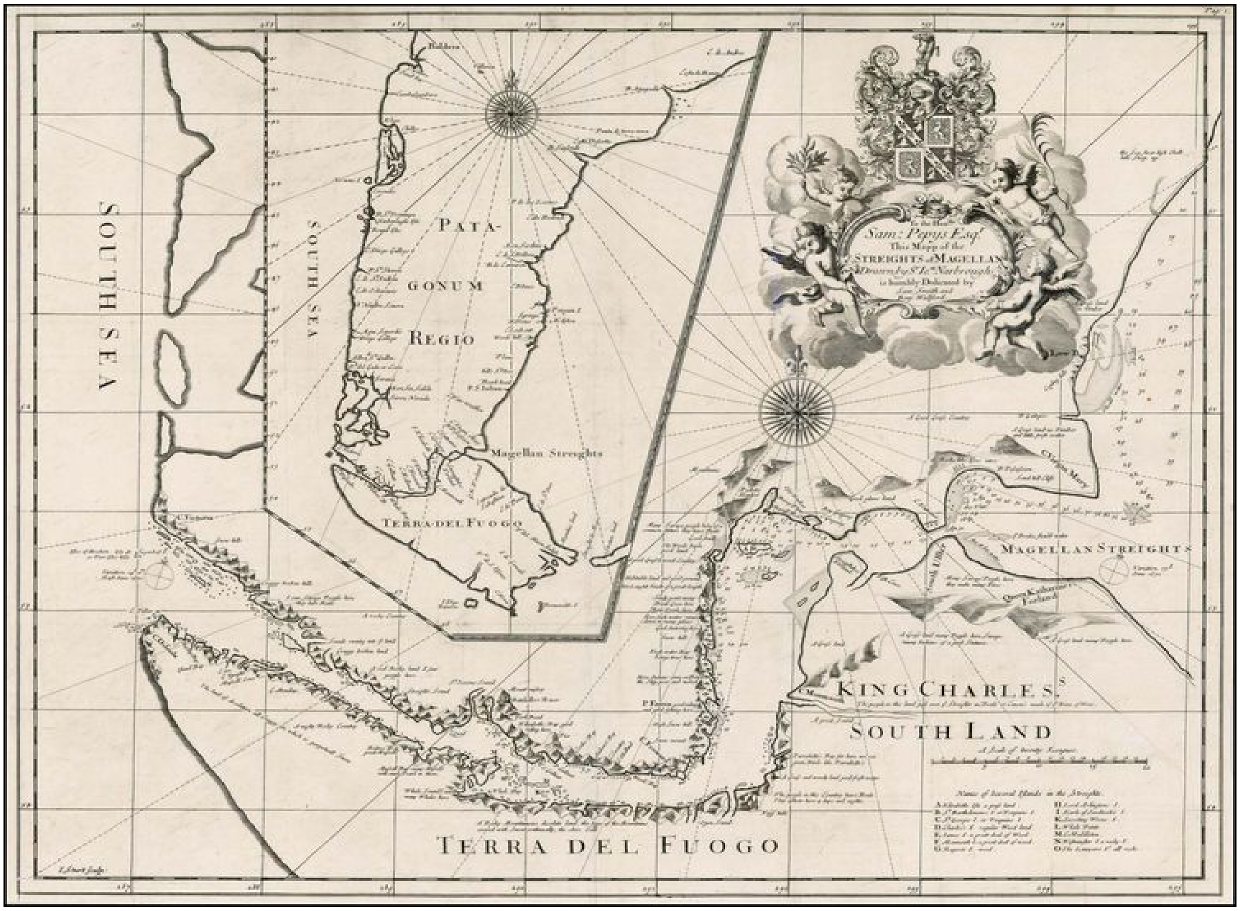
[80] Barone, 225, notes that "it was William III who made England for the first time a world power. … [England's only previous] lunge toward world power was the expansion of the navy, Started by Charles I and financed by his resented ship money in the 1630s, expanded by Cromwell in the 1650s, then carried on by James, Duke of York, the Earl of Sandwich, and the civil servant Samuel Pepys in the 1660s and after."

The South Sea Bubble: Financial Folly and Maritime Myths

Even though the South Sea Company was formed as a direct result of wresting the *Asiento* from Spain after the War of Spanish Succession (see Chapter 9), the English, since Tudor times had dreamed of opening the Pacific trade routes by either establishing a colony at Cape Horn or finding a Northwest Passge.[81] After Drakes's voyage the English launched a number of expeditions to the region for both piracy and discovery. Despite numerous colonial failures the dream of acquiring the wealth of Cathay through the South Seas persisted with the same durability as the dream that indirectly sponsored English artic exploration. The growing proficiency of England's mariners and specically their avid chart making skills contributed greatly to this persistence.[82]

[81] Edmundson, William, *A History of the British Presence in Chile: From Bloody Mary to Charles Darwin and the Decline of British Influence*, 3-4, notes in his study of British historical relations with and in Chile, "As early as 1570, a group of Englishmen thought of establishing a colony near the Magellan Strait as a base for incursions into the Pacific, but it was not until 1574 that the venture was given shape." He adds, "In March 1574, the Council received a petition from Richard Grenville, representing William Hawkins and a group of West County investors, for a voyage to the South Sea. … Francis Drake knew of this proposal, and when he set out in 1577 on his great voyage of circumnavigation, he followed a plan drafted by Walsingham, that had been presented to, and sanctioned by, Queen Elizabeth."

[82] Rodger, *Command*, 275, notes that one of the leading skills of the Royal Navy was operational chart-making, even long before the creation of the Admiralty's Hydrography Office. This dedication to accurate coastal charting by so many captains abroad was critical to British success in amphibious operations in 1756 in India. The Royal Navy even at this early stage was a learning culture as we shall see below in regards to its sponsorship of scientific expeditions.



Map 8.1. Sir John Narborough's Chart of the Strait of Magellan (1671). Narborough's very accurate chart was used for over 100 years. He dedicated it (originally) to Sam Pepys, Esq., First Secretary of the Admiralty. However well patronized, all British Patagonian and Chilean colonization efforts failed due to the ire of the Spanish and the very inhospitable environment. This chart "demonstrated the falsity of the accredited wisdom that the wind and currents would prevent any west to east passage of the Strait of Magellan."[83] Drake's Passage is shown, but there was no sailing west to east of it by the British until 1681, when Bartholomew Sharpe made the trek upon returning from his three year piratical expedition with William Dampier.

The South Sea Bubble of 1720, one of the first great euphoria induced stock market collapses, might not have been possible without these aggressive British maritime forays into Spanish South America and the Strait of Magellan, and more specifically without Sir John Narborough's chart. Peter Barber notes that his successful passage of the Strait in both directions encouraged ambitions for English South Seas trade. The British created a public-private partnership in 1711 for merchants to exploit these opportunities, but also with the

[83] Barber, Peter, Expert Advisor's Executive Summary of *A Manuscript Journal and Charts of Sir John Narbrough, 1666-1671*, British Library, 10 March 2009, 3. Image from Artscouncil.org.uk, http://www.artscouncil.org.uk/media/uploads/case_hearings_2008_9/Case_21expert_advisers_submission_100309.pdf.

purpose of reducing the national debt built up from the ongoing War of Spanish Succession.[84] The South Sea Company, specifically *The Governor and Company of Merchants of Great Britain, Trading to the South Seas and other Parts of America, and for the Encouraging the Fishery, &c*., like many internet companies of the 1990s never produced profits on any scale related to its hype. Spanish control of South America made the prospect of successful trade in the region unlikely. But this did not dampen the optimism of the day nor the public belief in easy seaborne wealth. Even the great Sir Isaac Newton was not immune to the national mood as the chart below amply demonstrates. All these hopes, private and public, according to Barber "ultimately culminated in the financial disaster of the South Sea Bubble and subsequent Crash. It is almost inconceivable that the 'bubbles' would have been generated in the first place had Narbrough not sailed back successfully through the Strait."[85] Substantial English trade through the Strait did not materialize in the late seventeenth or early eighteenth centuries despite British strategic success in the War of Spanish Succession. The British public learned that joint stock companies, even those with government's imprimatur, could defray risk, but they could not eliminate it completely, especially if the underlying business assumptions were unsound. However dismal the maritime influence on the cupidity of English speculators, the maritime project did have a very positive impact on English scientific advancement. As the politically convulsive seventeenth century passed, English society created many of the norms of modern science, often in conjunction with the maritime project.

[84] Price, Tim, *Sovereign Man*, https://www.sovereignman.com/finance/how-isaac-newton-went-flat-broke-chasing-a-stock-bubble-13268/, Monopoly trading privileges were granted in exchange for the company assuming England's war debt.

[85] Barber, 4, further notes as evidence that "the date of the printed map of the Strait of Magellan, dedicated to Robert Harley, the 'father' of the South Sea Company, suggests that the now lost manuscript map of the Strait may have been removed from the volume in connection with the speculation at some time between 1711 when the Company was founded and 1720 when the bubble burst."

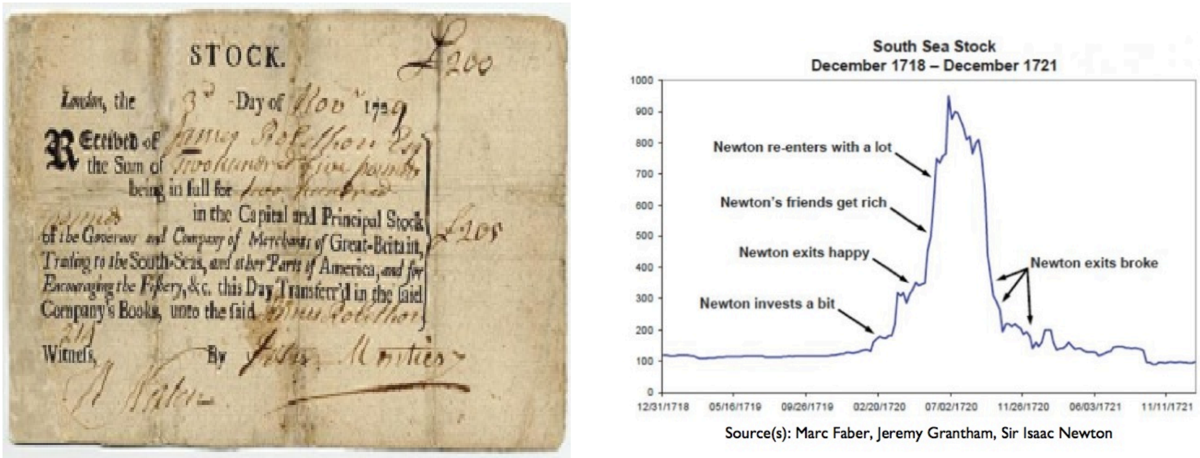


Figure 8.3. South Sea Stock: the Bubble, the Crash, and Newton's Ride. To the left is a stock certificate from *The Governor and Company of Merchants of Great Britain, Trading to the South Seas and other Parts of America, and for the Encouraging the Fishery, &c.*[86] The British elite and public, encouraged by Narborough's successful two-way navigation of the Strait of Magellan, and in the attempted fulfillment of Walsingham's dream of profitable South Sea trade by that route, subscribed beyond economic reason. The chart to the right displays the trajectory of South Sea Company stock from 1718 to 1721, "and … Newton's emotional journey from greed to satisfaction and then from envy and more greed, ending in despair. This prompted him to add, allegedly, that 'I can calculate the movement of stars, but not the madness of men.'"[87]

The Birth of English Science and the Sea

Like much else concerning England's early scientific and maritime expansion, we must look back to the late Tudor and early Stuart dynasties. We should pay special attention to an archetypal figure, Francis Bacon. He served as an emissary for Walsingham, Leicester, and for his uncle Lord Burleigh under Queen Elizabeth and rose to prominence in the Stuart court as James I's Attorney General and Lord Chancellor of England, eventually falling from grace. However, his most lasting impact concerns his philosophical writings on the proper procedure for dispassionate scientific inquiry.

Francis Bacon, unsatisfied with the Aristotelian philosophic method which relied on deductive syllogisms to interpret nature, and which was prevalent among natural philosophers in sixteenth century Western Europe, penned a corrective to this approach in his seminal work,

[86] Colombo, Jesse, "The South Sea Bubble," The bubblebubble.com, http://www.thebubblebubble.com/south-sea-bubble/.
[87] Price, "How Isaac Newton went flat broke chasing a stock bubble," Sovereignman.com, https://www.sovereignman.com/finance/how-isaac-newton-went-flat-broke-chasing-a-stock-bubble-13268/.

Novum Organum. Bacon's presented his 'New Instrument' or tool of analysis, 'the scientific method,' as one more efficient for uncovering objective truth. His method, mandated 'objective' observation, embraced unanticipated outcomes, privileged the dispositive, and used inductive reasoning. The Baconian method has been the structural basis for Western science for four centuries and is thoroughly ingrained in our intellectual baggage, but at the turn of the seventeenth century, Bacon felt a need to 'sell' his approach as one superior to the prevalent Scholastic and Aristotelian approaches used by most medieval scholars.

Bacon's basic objection to the use of deductive logic as a method of natural inquiry rested on the reasonable observation that logic, no matter how flawless its application, cannot derive truth from erroneous presumptions.[88] Bacon delineated four categories of erroneous presumptions "besetting human minds." These 'Idols' were those of the Tribe, the Cave, the Market-place, and of the Theater.[89] Idols of the Tribe are endemic to humanity itself and encumber us all with preconceived ideas and an innate desire to affirm what we think we know. Idols of the Cave (drawing on Plato's allegory) are particular to each individual. The individual's 'reality' is built from experience, education or affiliation and thereafter clouds objectivity and posits one's personal experience as the touchstone of truth. Idols of the Market-place concern words, the social freight they carry, and the trap engendered by the inadequacies and coercive directive imbued in language.[90] Lastly, Idols of the Theater concern philosophical sects, superstitions, and the inappropriate mixing of natural philosophy (physical science) and theology. This last Idol leads to three problems: "Sophistical [logic predominates], Empirical [over generalizations run rampant], and Superstitious [were conflation of science and religion

[88] Bacon, Francis, *Novum Organum*, with other parts of The Great Instauration (1620), translated and edited by Peter Urbach and John Gibson, Aphorism I, 14, pg. 46.
[89] Ibid, Aphorism I, 39, pg. 53.
[90] Bacon predated Ludwig Wittgenstein and the classical and postmodern social theorists with his insight into the social origin, directive nature, and limitations of language by three centuries.

retards both]."[91] Having categorized the different limitations in humans and their institutions involved in searching for truth in nature, Bacon presented his inductive method as a tool useful in dispelling subjective predispositions and for discovering 'objective truth.' Whether we accept Bacon as the originator of inductive reasoning in the natural sciences or just its English scribe, it is important to note that the epistemological change that he espoused was emblematic of the spirit shared by seventeenth scholars exploring the new natural sciences on both sides of the Channel.[92] The new instrument of science, inductive reasoning through natural observation and experimentation, would become the dominate method of inquiry, and both it and peer review would become institutionalized through new academies separate from the colleges and universities established by and for the new scientific practitioners to showcase their discoveries. These academies also served the interests of the seventeenth and eighteenth century state builders by addressing their most pressing concerns. And quite often, these concerns were nautical.

[91] Bacon, *Novum Organum*, Aphorism I, 62, pg. 68.

[92] It is important to caveat this assertion with the counter claim made by Steven Shapin and Simon Schaffer in their 1985 SSK case study presented in *Leviathan and the Air Pump.* Their examination of the particular debates between the Royal Society experimental exemplar Robert Boyle and the political philosopher Thomas Hobbes, lead the authors to make the assertion that "Solutions to the problem of knowledge are solutions to the problem of social order." (332) They reject the notion that experimentation and inductive reasoning lead to uncovering objective truths about the natural world. Rather Shapin and Schaffer are concerned with the "rules of the game" and how these came to be established in the sociological truth verification regime of early modern English science. The authors focus on the contest within the heterogeneous community of the time – theirs is a story of contest and the battle for methodological ascendency. It specifically rejects a uniform essence or spirit of inquiry for the period. Shapin and Schaffer explicitly cast their work as an interdisciplinary study. They examine both the 'problem of knowledge' and the 'problem of social order' in their period tract despite the former traditionally being the purview of philosophy and the latter of sociology. In fact, they argue that these are "the same problem." (xlix) The authors examine why Hobbes has been expelled from history of science. They want to address the problems with 'Whig' historiography which asymmetrically treats the arguments of the winners and losers, treats the opinions of the former as knowledge and the later as error, and where the "historian accomplishes [this] by taking the side of accepted knowledge" (11) and adopts the winning arguments as his own.

The Royal Society and Nature's Book

Although the founders of the Royal Society venerated Bacon as their inspiration, a number of scholars contend that its founding was in practice an evolution of the astronomical, mathematical, and navigation college and university networks that had been created to solve the pressing navigation problems of England's mariners. Waters observes that

> "In the middle of the seventeenth century, out of the informal gatherings customary in the rooms of the Gresham professors of astronomy and geometry after their lectures, was developed the first scientific society in the English-speaking world – the Royal Society."[93]

This claim is supported by more than the fact that the Royal Society, to include its's library and collections, was housed in Sir Thomas Gresham's buildings from its founding in 1660 until it purchased its own buildings in 1710, or from early references to Fellows of the Royal Society (FRS) as 'Greshamites' or 'Men of Gresham.'[94] Francis Johnson notes that the most active early members of the Royal Society were Gresham professors, to include the chairs of Astronomy, Geometry, and Physic.[95] Gresham's central location in London and its active network of mathematicians, astronomers, and navigators, helped establish the pattern of open exchange of ideas and public testing of theories that were to become emblematic features of the future Royal Society. In addition to the navigation, mathematics, and astronomical connections between the English maritime community and Gresham addressed in the previous chapter, Johnson notes that

> "From the early years of the seventeenth century there is evidence of a close association, in scientific investigations, of the Gresham College professors and the sea captains, the shipbuilders, and the administrative officials of the English Navy."[96]

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[93] Waters, 245-246, recommends F.R. Johnson, "Gresham College, Precursor to the Royal Society," *Journal of the History of Ideas*, Volume I (1940) and his *Astronomical Thought in Renaissance England* (Baltimore, 1937). Waters also cites Forest Watson's *The Beginning of the Teaching of Modern Subjects in England* (1909).
[94] Johnson, F.R., 414, notes that there was a seven year hiatus following London's great fire of 1666.
[95] Ibid, 415-416, proposes a theory of a long evolution from informal club to organization at Gresham since its founding in 1598, rather than being a creation of Robert Boyle and his colleagues dating to their meetings in 1645.
[96] Ibid, 429, cites an example of Briggs resolving a controversy among shipwrights including Phineas Pett. He notes Gunter's associations with navy officials at Deptford and a Gresham professor John Wells who also served as Keeper of His Majesty's Naval Stores at Deptford, Chatham, and Portsmouth.

Although there may have been intellectual precursors to the Royal Society to include Dr. Dee's Mortlake or the *Accademia dei Lincei* of which Galileo was a member, Gresham College and with it, its circle of maritime interests, can safely assert immediate ancestry to the Royal Society and as we shall detail below, close association in its formative years.[97]

Even though The Royal Society bore the imprimatur of Charles II, receiving his formal patronage in 1662, it was largely, in the words of E.G.R. Taylor, an amateur society. It was loosely organized and the research of its members was largely driven by each fellow's personal interests.[98] This stood in stark contrast to the French *Académie Royale des Sciences* created in 1666 by Jean-Baptiste Colbert.[99] It was comprised of scholars paid directly by Louis XIV and whose research program was largely directed by his ministers.[100] Taylor observes that the professional and state directed science of the French at first produced concrete practical knowledge more readily than the *laissez-faire* English model. She cites the example of the exact measurement of the length of a degree of the meridian. As we discussed in Chapter 7, the relationship between the degree and nautical miles was becoming essential to accurate chart making and for logging one's distance travelled. The English offered small prizes for its determination, but Colbert put French resources behind the effort and financed Jean Picard's two-year (1669-1670) triangulation exercise that more closely approximated the distance than

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[97] Drake, Stillman, "The Accademia dei Lincei," *Science, New Series,* 1194-1195, notes that the society founded in 1603 in Rome has some claim to be the first scientific society due to its printed goals of discovering natural phenomena , searching for new discoveries, and publically publishing its findings. It could boast Galileo as a member. Founded by an eighteen year old noble, Frederico Cesi, second marquis of Monticelli, the society's founding quartet also boasted the Dutch physician Johannes Eck.

[98] Lyons, Henry, *The Royal Society 1660-1940: A History of its Administration Under its Charters,* 70, notes that although the Fellows of the Royal Society lacked the financial and material support of their French compatriots, they "enjoyed the priceless boon of complete independence."

Ferreiro, 57, notes that "it was 'Royal' in name only, as no government funding came its way."

[99] Ferreiro, 57-58, notes that in his capacity as Finance Minister, Colbert granted the members of the Montmor Academy a charter in 1666. It was government funded to solve technical problems of national importance.

[100] Taylor, *Haven-Finding,* 236.

Lyons, 69, notes that in addition to their salaries, the French savants had an observatory built for them.

had Norwood's personal endeavor (to within approximately 0.578% of our modern reckoning), but had the unfortunate political result of reducing the size of Louis XIV's kingdom as more accurate latitude measurements revealed longitudinal errors on the maps of the day.[101]

Ferreiro notes that "the Academy of Sciences had traditionally strong ties with the French navy."[102] These ties went further than Colbert, who as Minister of the Navy (or Secretary of State for the Marine) also founded schools of hydrology for navigation and piloting for the merchant marine. Like the grandees that ran the Tudor and Stewart governments and navy, there was a good deal of overlap between the Early Modern state makers and the new academies of science. Just as Lord William Brouncker and Samuel Pepys in England had dual naval and Royal Society roles, Jean-Frédéric Phélypeaux, Count of Maurepas, Colbert's successor as the Secretary of State for the Marine, was an honorary vice president of the French Academy.[103] In addition to paying their fellows and targeting their research toward technical issues of concern to the state, the French initiated the Rouillé Prizes to spur research.[104] Ferreiro observes that a plurality of these were aimed at naval issues. He notes that "of the 80 Rouillé Prizes proposed between 1720 and 1792, almost a quarter concerned fluid mechanics and maritime subjects."[105] These state ministers were pioneering government sponsored research grants. The French governments under Colbert and Maurepas prioritized not just building naval strength but expanding the nautical scientific cannon which undergirded all marine endeavors.

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[101] Taylor, Haven-Finding, 236-238, notes that the Royal Society by contrast offered Edmund Halley £50 to complete the task. Picard's measure of 366,669 English feet, or 69 miles 783 yards, was only 706 yards off Richard Norwood's earlier measurement.

[102] Ferreiro, 3-6.

[103] Rodgers, P.G., 30, "In 1664 yet another additional [Naval Board] commissioner was appointed: Lord Brouncker, the first President of the Royal Society and a close friend of the diarist John Evelyn." This was upon the reinstatement of the office of Lord Admiral (the Admiralty) and the Navy Board by Charles II at the beginning of the Restoration. Brouncker was also an accomplished mathematician.

Maurepas served Louis XV as Minister of the Marine from 1723 to 1749.

[104] Ferreiro, 121, these prizes were endowed in 1714 by Jean Rouillé, count of Meslay.

[105] Ibid, 58, 121, also notes that "The academies were funded by the French government as a means of using scientific investigations to support policy; in this sense, the prizes were a sort of research contract proposed by the government through the intermediary of the academies."

Even though the English Royal Society was not state directed and its researchers unpaid, this does not mean that state actors and mercantile parties could not get their pressing issues addressed. In addition to cementing inductive reasoning, experimentation, and observation as the proper methods of inquiry into natural phenomena, The Royal Society established the modern scientific standards of peer review, public demonstration, and widespread dissemination through publication as pillars of the emerging natural sciences. A cursory review of their first published issue of *Philosophical Transactions* illustrates the symbiotic relationship that existed between the metropolitan scientists and the maritime community.

Maritime Concerns in the First issue:

- Auzout, Adrien [Monsieur]. "Directions for Sea-Men, Bound for Far Voyages". *Philosophical Transactions* **1** (1665-1666): pp. 140-143.
- Auzout, Adrien [Monsieur]. "An Appendix to the Directions for Seamen, Bound for Far Voyages". Philosophical Transactions **1** (1665-1666): pp. 147-149.
- Boyle, Robert. "A Narrative Concerning the Success of Pendulum-Watches at Sea for the Longitudes". *Philosophical Transactions* **1** (1665-1666): pp. 13-15.
- Boyle, Robert. "Other Inquiries Concerning the Sea". *Philosophical Transactions* **1** (1665-1666): pp. 315-316.
- Montagu, Edward [1st Earl of Sandwich]. "An Account of Some Observations, Lately Made in Spain, by His Excellency the Earl of Sandwich". *Philosophical Transactions* **1** (1665-1666): pp. 390-391.

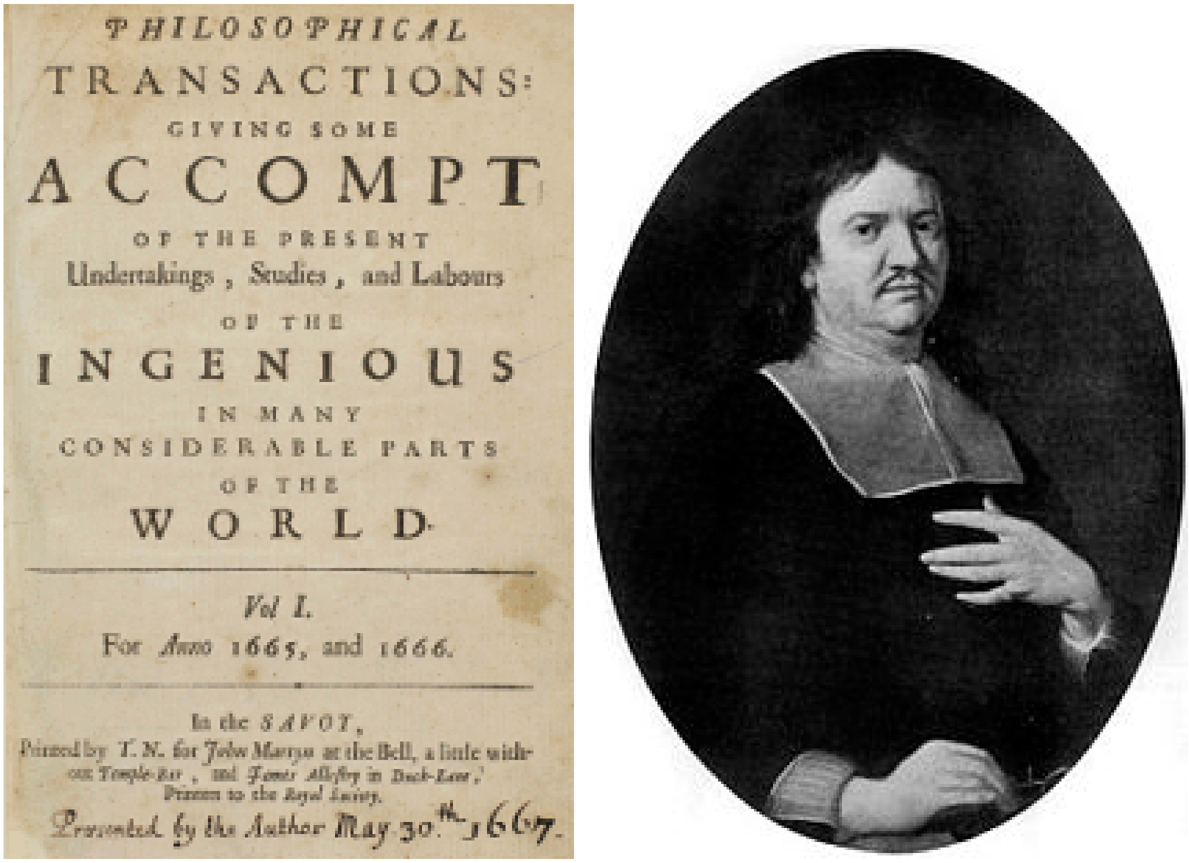

Figure 8.3. Inaugural Edition of the World's First Science Journal. "In 1662, the newly formed 'Royal Society of London for Improving Natural Knowledge' was granted a charter to publish by King Charles II and on 6 March 1665, the first issue of *Philosophical Transactions* was published under the visionary editorship of Henry Oldenburg [pictured to the right], who was also the Secretary of the Society.[106] The first volumes of what was the world's first scientific journal were very different from today's journal, but in essence it served the same function; namely to inform the Fellows of the Society and other interested readers of the latest scientific discoveries. As such, *Philosophical Transactions* established the important principles of scientific priority and peer review, which have become the central foundations of scientific journals ever since. In 1886, the breadth and scope of scientific discovery had increased to such an extent that it became necessary to divide the journal into two, *Philosophical Transactions A* and *B,* covering the physical sciences and the life sciences respectively."[107]

Adrien Auzout's directions for mariner data collection follow in the great tradition pioneered by the first Portuguese voyages of discovery. Auzout was one of Picard's assistants in his latitude endeavor, and the co-inventor with him of an improved micrometer.[108] He petitioned Louis XIV for the funds to build a public observatory in 1664 and it was completed three years later almost a decade before Charles II commissioned the Royal Observatory at Greenwich. He

[106] Image from En.wikipedia.org, https://en.wikipedia.org/wiki/Henry_Oldenburg#/media/File:Henry_Oldenburg.jpg.
[107]The Royal Society Publishing Company, London, 2015, http://rstl.royalsocietypublishing.org/.
[108] Taylor, *Haven-Finding*, 237.

was a founding member of the *Académie Royale des Sciences* from 1666 to 1668 and served as its first secretary. In that position, Auzout corresponded frequently with the Secretary of the Royal Society Henry Oldenburg despite the rivalries between their nations. Auzout left the French Academy and became a Fellow of the Royal Society before traveling to Italy.[109] His petition to sailors in the Society's inaugural edition illustrates both the need the metropolitan researchers had for hard data from mariners and the manifold nautical problems the metropolitan scientists were attempting to resolve for mariners.

In his "Directions for Sea-Men, Bound for Far Voyages," Auzout explains that

> "It being the design of the R. Society, for the better attaining the End of their institution, to study *Nature* rather than *Books*, and from the Observations, made of *Phenomena* and Effects the presents, to compile such a History of Her; as may hereafter serve to build a Solid and Useful Philosophy upon, …"[110]

After citing Gresham College, Trinity House, and the Lord Admiral James Duke of York, as authorities and forerunners, he goes on to ask for nine specific categories of data for all mariners to collect, record, and return to the Society.

(1) Observe declination of compass at various latitudes and longitudes (magnetic variation)
(2) Observe inclination of compass using dipping needles
(3) Mark ebbs and flows of sea [tidal data] and relation to moon phases
(4) Chart coasts, islands, and ports by bearings and distances
(5) Sound depths of same
(6) Identify composition of sea floor
(7) Weather log changes by latitude and longitude
(8) Meteorological observations
(9) Salinity tests by depth, latitude, and longitude[111]

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[109] Even from Italy, Auzout continued his coinnection with the Royal Society and his interest in maritime problems. In 1670 he contributed this article to the 5th volume of the society's journal: "An Observation of M. Adrian Azout, a French Philosopher, Made in Rome (Where He Now is) about the Beginning of This Year 1670. Concerning the Declination of the Magnet: Out of an Italian Printed Paper, English'd by the Publisher, as Follows (*Phil. Trans.* January 1, 1670 **5** 1184-1187; doi:10.1098/rstl.1670.0021)
[110] Auzout, Adrien, "Directions for Sea-Men, Bound for Far Voyages," *Philosophical Transactions* **1** (1665-1666), 140-141.
[111] Ibid, 141-143.

In his “An Appendix to the Directions for Seamen, Bound for Far Voyages,” Auzout provides specific instructions and an equipment list akin to the Portuguese *Regimento do Astrolabio e do Quadrante* except that he has a much broader purpose and a more professional user. He also describes two test methods developed by Robert Hooke for (1) Sounding of water depths without a cord (lead and line), and (2) Retrieving water at variable depths for temperature and salinity tests. His instructions include not just data taking and recording procedures, but construction techniques with specifications for the devices to be employed.

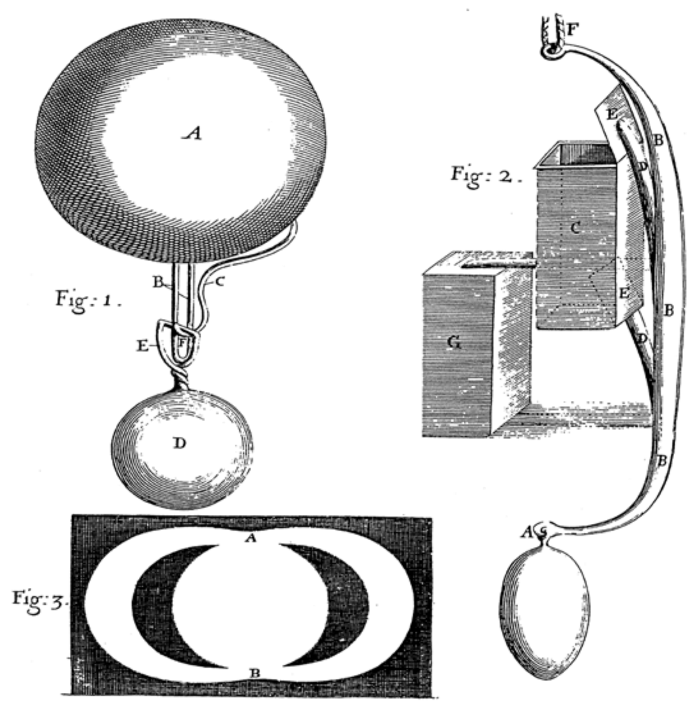


Figure 8.5. Robert Hooke’s Devices for Hydrographic Data Collection, 1665. These diagrams are provided in Monsieur Auzout’s “Appendix for Directions to Seaman” and detail operation and device construction. Figure 1 (and A, B, C, D and E) - Sounding of water depths without a cord (lead and line) Same “black box” theory as original Portuguese solar declination readings compared to *altura* and latitude tables – seamen employ device, record findings and compare time to resurface released globe to a table pre-made by experimenters and theoreticians in metropolis. Figure 2 - Bucket for retrieving water at variable depths for temperature and salinity tests.[112]

[112] Auzout, Adrien, “An Appendix to the Directions for Seamen, Bound for Far Voyages,” *Philosophical Transactions* **1** (1665-1666), 147-149.

The other marine articles in this issue are also worthy of note. Robert Boyle discourses on the great maritime problem of the age, ascertaining longitude at sea. His concern is mechanical, not theoretical. Boyle recognized that longitude determination was a clock making problem and the seventeenth century state of the art was inadequate to the task. Although his description of the test conducted by Major Holmes to the Cape Verde Islands was overly optimistic, Boyle was accurate in his assessment of where the eventual solution would lie. The pendulum clocks he described could not operate reliably on a pitching ship deck, despite his test results; a new type of timing mechanism was required. His second article once again is a request for hydrological data concerning salinity and specific gravity of sea water in various locations, among other natural and possible medical phenomena. At the dawn of the modern era, the desire to measure and catalogue natural phenomena from around the globe was acute. Mariners provided these new natural scientists the access they lacked.

The mariners who provided this data came from all social strata in the maritime community and from both its merchant and naval wings. The inaugural issue of *Philosophical Transactions* has a report from the First Earl of Sandwich on his voyage to Spain. Edward Montagu represented the power class in both Cromwell's Protectorate and Charles II's Restoration England. He was a Fellow of the Royal Society and played a pivotal role in two of the Anglo Dutch wars, dying at the Battle of Solebay in 1672. However, while returning from his posting as ambassador to Spain, he took a number of astronomical observations, determined latitudes, made lunar observations, and made several observations of the Jovian moons. During this explosion of English ships upon the world's oceans, every mariner, both low and high, was encouraged to become part of the data accumulation project directed from London.

The Age of Sail and the birth of the natural sciences were concomitant phenomena and the interaction between the two projects was intense and many actors straddled both projects. The new scientists or natural philosophers could not compile their book of nature without global access. This access was enabled by Early Modern European sailing and astronomical technology and more than one power had seen the financial and political impacts of expanding that canon to guide their ships, open trade routes, and build colonial empires. Sailing technology and scientific inquiry both became investment opportunities for the state makers of the period. France and England built their first public astronomical observatories – the first government science buildings of the modern era – for both astronomical and navigational purposes. When Charles II appointed his first Royal Astronomer, his proclamation left no doubt as to his motivation. John Flamsteed was to serve as the director of the observatory and to

> "Apply himself with the most exact care and diligence to the rectifying of the tables of the motions of the heavens, and the places of the fixed stars, so as to find out the so much desired longitude of places for the perfecting of the art of navigation." [113]

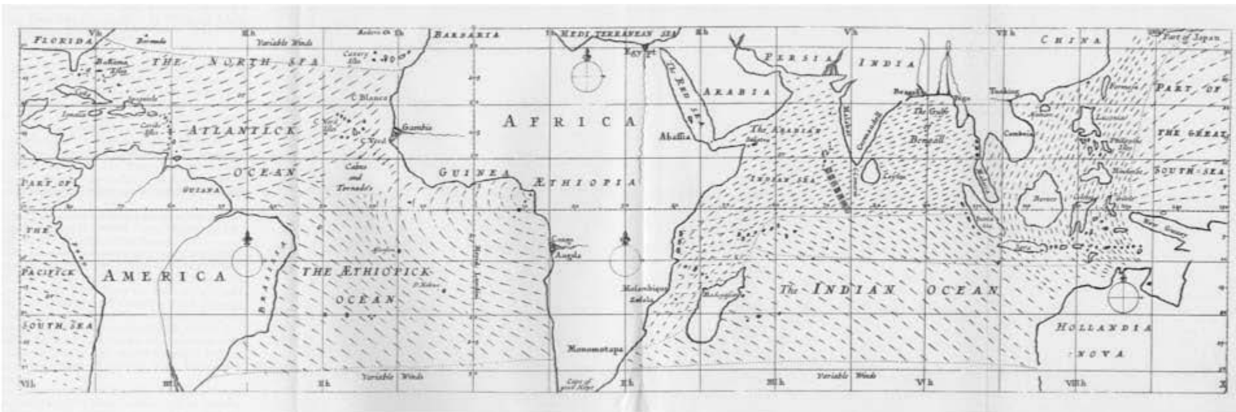
Governments or the powerful funded either directly or indirectly scientific research with an eye toward investment returns, naval advantage, or power accumulation. The sea was useful and its exploitation required the development and expansion of the natural sciences.

From Halley to Cook – Maritime Necessities

An iconic figure who both assiduously collected the data flowing in from overseas and even launched expeditions himself to gather data was the astronomer Edmund Halley. Halley's pursuit of maritime knowledge with practical uses made him instrumental in the creation of the sciences of meteorology and hydrology. In 1686, Halley attempted to systematically chart the

[113] The Greenwich observatory was commissioned in 1675 by King Charles II, who also created the position of Astronomer Royal and appointed John Flamsteed. Christopher Wren, London's great post-fire architect built it.

major wind patterns of the planet and their predictable changes with the seasons.[114] His thermal hypothesis for wind flow helped replace the hitherto accepted wisdom of eastward moving winds toward the *primum mobile* (the turning heavens of the geocentric model) which had been rendered specious by the worldly knowledge of oceanic sailors.[115]



Map 8.2. Edmund Halley's Map of Global Trade Winds, 1686.[116] Presented to the Royal Society, this map was unique at its time. Halley charted the prevalent wind systems of the globe with the exception of most of the Pacific Ocean. Without access to the captains and pilots of the Philippine Galleon of Spain, English knowledge of this region would have to await Captain Cook. The usefulness of this study to mariners, who provided the disparate data points, was immense. The map depicts the major reversal of the trade winds between the winter and summer monsoons of Asia and Australia by using shorter dashes.

Halley's contributions to England's nautical canon and his proposals to chart the oceanic currents in the English Channel led Samuel Pepy's to take the unprecedented step of giving him a temporary Captain's commission in the Royal Navy to conduct this survey.[117] The resulting chart and its military uses prompted Pepys to again sponsor Halley to command the world's first purely scientific oceanic voyages. He took the ship *Paramour* to the South Atlantic in 1698 in

[114] Taylor, *Haven-Finding*, 238-239. His preliminary interest in the subject was spurred by his year spent on St. Helena in the South Atlantic as a young man cataloguing the southern stars.
[115] "Edmond Halley, 1656–1742," Libweb5.princeton.edu, http://libweb5.princeton.edu/visual_materials/maps/websites/thematic-maps/quantitative/meteorology/meteorology.html, 2017, Halley produced the world's "first meteorological map, charting the directions of trade winds and monsoons. … He attributes the circulation of prevailing winds to the solar heating of volumes of atmosphere as the earth revolves, which thus draw air after them, forming a generally easterly wind; as the sun departs, the air reverses direction to establish equilibrium. He argues that the effects of continents (and other landmasses) and latitudes complicate but do not compromise the basic principle. (Today, of course, solar heating is viewed as only a piece in the puzzle of winds; ocean currents would be another."
[116] Slingo, Julia, "The Evolution of Climate Science: A Personal View from Julia Slingo," https://public.wmo.int/en/resources/bulletin/evolution-of-climate-science-personal-view-from-julia-slingo.
[117] Taylor, *Haven-Finding*, 239-240.

order to measure latitude, magnetic declination, and longitude.[118] He followed this voyage with command of *William III* in 1699 to 1700. In 1701 he published the world's first isometric map providing sailors current magnetic variation in all the areas of the world with the exception of the Pacific Ocean.

Halley's pioneering efforts in both meteorology and hydrology greatly aided mariners at sea just as their inputs made the birth of these sciences possible. Other meteorological breakthroughs at the end of the seventeenth century marrying centuries of observation with theory produced more benefits to the oceanic project. Probably most significant was the use of the barometer and the relation between its rise and fall signaling changing weather ahead.[119] But once again, it would be advances in instrument making, an area of English national skill, were some of the biggest advances would come at the dawn of the eighteenth century. The two most useful instruments and their derivatives for mariners would prove to be telescopes (to include the new science of optics) and clocks.

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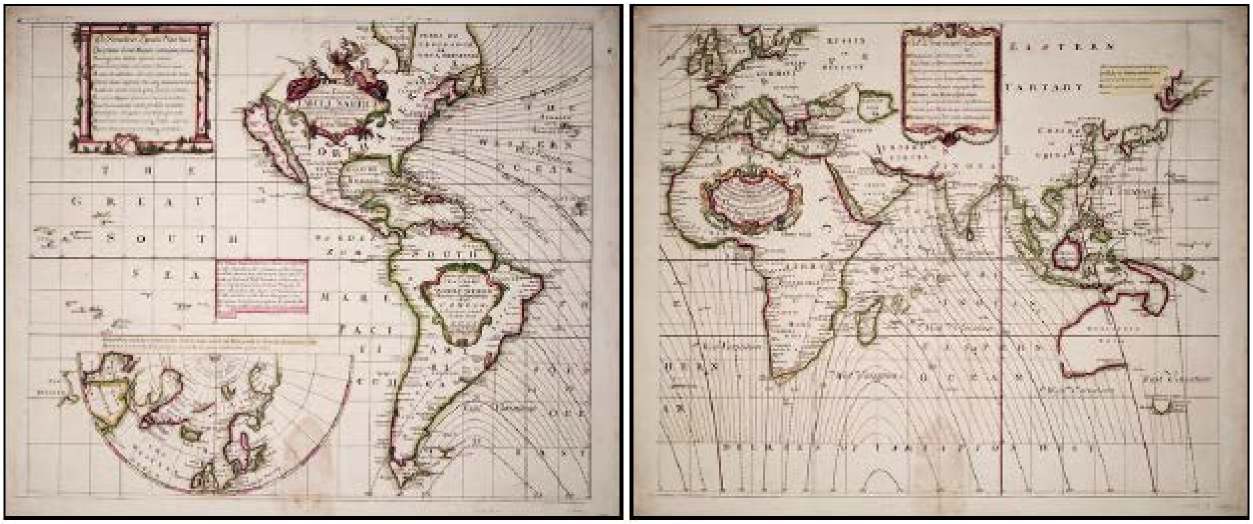
[118] "Magnetic Deviation: Comprehension, Compensation and Computation (Part I)," Myreckonings.com, http://myreckonings.com/wordpress/2009/04/18/magnetic-deviation-comprehension-compensation-and-computation-part-i/, "The longitude was found by observing eclipses of the moons of Jupiter to retroactively determine universal time when compared against these events as recorded in England."
[119] Taylor, *Haven-Finding*, 243.



Edmund Halley's 1701 map of the known magnetic variations of the world.

Map 8.3. ***A new and correct sea chart of the whole world showing the variations of the compass as they were found in the year M.D.CC.*****, by Edmund Halley.** "His 'Curve Lines' of equal magnetic variation (today called **isogones**) were first used by Christovao Bruno in the 1620s, but this is the earliest surviving example of such a map. Captain James Cook used a copy of Halley's map on his voyages around the world."[120] These are also referred to as Isogonic maps.

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[120] "Magnetic Deviation: Comprehension, Compensation and Computation (Part I)," Myreckonings.com, http://myreckonings.com/wordpress/2009/04/18/magnetic-deviation-comprehension-compensation-and-computation-part-i/.

Improvements in astronomical instruments throughout the seventeenth century both ashore and afloat greatly improved the precision of stellar, lunar, and solar observations. As precision increased so did the accuracy of the data generated and the maritime demand for better astronomical tables. Behind all of these demands for better instruments and astronomy, however was finding the solution to one looming problem: fixing longitude at sea. The first breakthrough in improving seaborne instruments was indeed a result of this quest.

As mentioned in Chapter 7, footnote 51, the state of the art device for taking celestial observations at sea in the seventeenth century was the Davis Quadrant or back-staff.[121] As we discussed, the problem of the earlier cross-staff concerned solar glare and parallax errors caused by the eye's distance from the rod. John Davis had avoided the problems of the cross-staff, requiring his observer to read shadow and horizon, rather than ascertaining solar height by staring directly at the sun while simultaneously fixing the horizon.[122] However, despite the improvements, better accuracy was required for solar observations and stellar and lunar readings could obviously not be taken due to the lack of a strong enough light to cast a shadow. And the problem of longitude and ascertaining accurate local time by using lunar location seemed to be the only solution to the mechanical imprecision of clocks. Peter Ifland notes that

> "Early in the 18th century, the astronomers had developed a method for predicting the angular distance between the moon and the sun, the planets or selected stars. Using this technique, the navigator at sea could measure the angle between the moon and a celestial body, calculate the time at which the moon and the celestial body would be precisely at that angular distance and then compare the ship's chronometer to the time back at the

[121] Cutler, Thomas J., *Dutton's Nautical Navigation,* 15th edition, 233, notes that the first truly successful instrument for measuring the altitude of celestial objects at sea was the cross-staff, but that since it required fixing both the celestial body and the horizon in one's eye, often on a pitching deck, that even the most experienced navigators could not attain an accuracy of greater than a degree. Davis's backstaff or quadrant on the other hand, by reading the sun's shadow cast with the horizon, allowed the mariner to fix just one body. Even though the original device invented by Davis in 1590 was only useful for fixing the sun, later versions of the device fitted with mirrors made the observation of other luminous objects possible.

[122] Davis, John, *The Seaman's Secrets,* 1594.

national observatory. Knowing the correct time, the navigator could now determine longitude." [123]

Once again however, this method required detailed lunar and stellar tables for all points sailed. The land tables could be more accurately generated by astronomers using ever improving telescopes, but once again accuracy of readings at sea remained the problem.

The leading luminaries of the Royal Society including Hooke and Newton developed optical devices to fix a distance from a star or the moon at sea. Hooke presented his instrument designed to measure the moon from a fixed star in 1670, four years after discussing his theory. Newton presented his instrument in 1699.[124] E.G.R. Taylor contends that neither instrument was expanded upon because at the end of the seventeenth century the Greenwich observatory had not yet generated the precise lunar and stellar tables required by theory.[125]

Time and another Fellow of the Royal Society would bring this project to fruition early in the eighteenth century.[126] John Hadley's device, created around 1730 and presented to the Royal Academy on May 13, 1731, was a reflecting octant with an angle measuring range of ninety

[123] Ifland, Peter, "The History of the Sextant," Lecture at the Physics Museum under the auspices of the Pro-Rector for Culture and the Committee for the Science Museum of The University of Coimbra, October 3, 2000, http://www.mat.uc.pt/~helios/Mestre/Novemb00/H61iflan.htm.

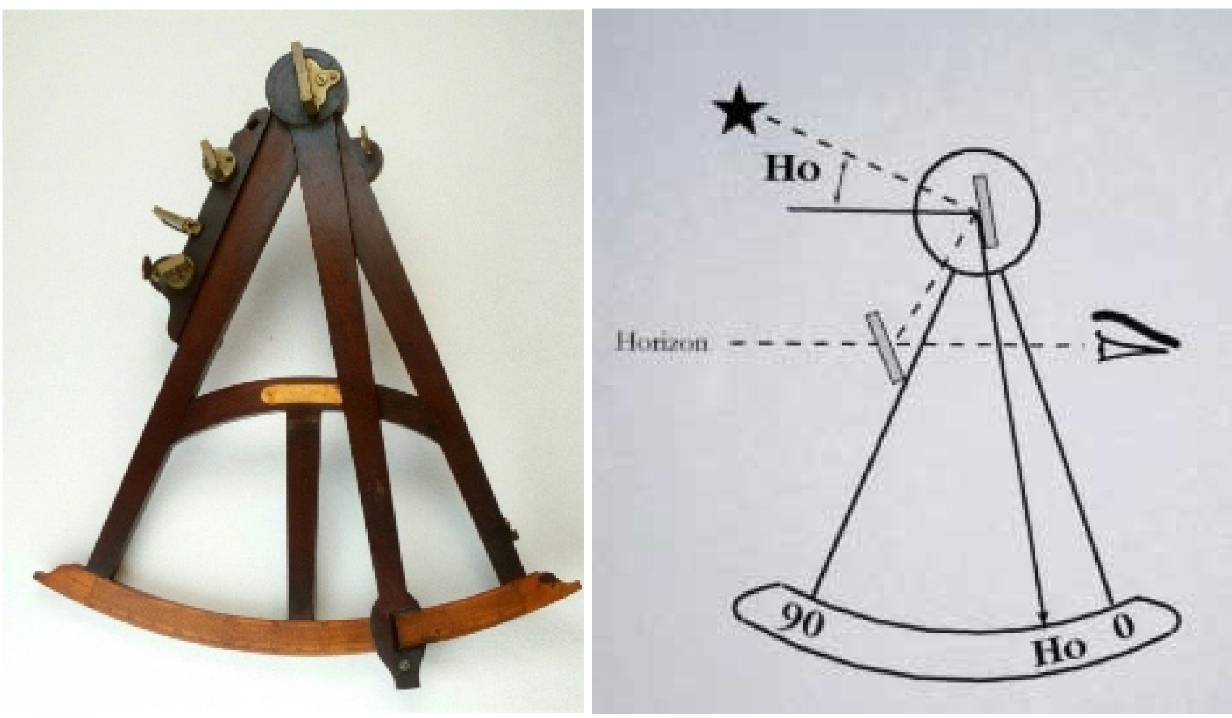
[124] Taylor, *Haven-Finding*, 252, notes that Hooke's device used a mirror on an alidade. He fixed the star or moon directly by line of sight and caught the reflection of the other. Newton used "a fixed and a moveable mirror attached to a quadrant, the former at the end of the telescopic sight."

Cutler, 233, also notes that the optical prinipals undergirding the sextant were first described by Newton.

[125] Sobel, Dava and William J.H. Andrews, *The Illustrated Longitude: The story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*, 114, notes that mathematics as well as astronomical data was lacking for success in this area. It would not be until the mid-Eighteenth century that the German mapmaker and mathematician Tobias Mayer would "make the breakthrough that enabled the lunar distance to become a practical way of finding longitude at sea." Mayer collaborated with the Swiss mathematician Leonhard Euler, using his equations in the calculation of his tables marking the distance of the moon to stellar objects (lunar occulations) and lunar eclipses at twelve hour intervals in order to calculste one's accurate time. He initially generated the method for land cartography, not navigation.

[126] Dreyer, J. L. E., "On the invention of the Sextant," *Astronomische Nachrichten*, **115:3** (1886)**,** 33-35, argues persuasively that the independent invention of the octant [precursor to the sextant] by John Hadley coincided with its simultaneous creation by Thomas Godfrey of Philadelphia. Even in the nineteenth century this argument over precedence was a century old. Also included in the dispute are plans by Sir Isaac Newton from 1699 for an instrument using two mirrors for ascertaining longitude at sea by "fixing" the location of the moon. What all of this reveals is that maritime problems, especially pertaining to longitude, occupied the finest scientific and mechanical minds on both sides of the Atlantic.

degrees (the “A” frame of the device itself was open to forty-five degrees or one eight of a circle, from Latin *octāns*). It was designed to measure the altitude of the sun or other celestial objects above the horizon at sea. It was later replaced with an instrument with a slightly larger arc of measurement (the sextant of one hundred and twenty degrees, with a frame angle of sixty degrees or one sixth of a circle) which more easily enabled lunar and stellar observations.[127] More importantly, its arrival followed decades of astronomical data accumulation by the first two Royal Astronomers and their staffs at Greenwich, John Flamsteed and his successor Halley. However, this device although dramatically increasing the reading of celestial accuracy at sea, did not alone solve the longitude problem.



Figue 8.6. Early Hadley Octant. This mahogany octant was made about 1760 by the famous London maker, George Adams.[128] A mirror mounted on a mobile arm which slides on an arc with degree marks reflects an image of a celestial body superimposed over the image of the horizon observed directly. The angle of the difference read between either two celestial bodies sighted (e.g. moon and Polaris) or between sun and horizon, is half of the actual measure, so it must be either doubled by the user or the instrument maker upon the scale itself.

[127] Innovating the sextant from the octant is usually attributed to Captain John Campbell of the Royal Navy and the instrument maker John Bird. Campbell was a protégé of Anson, a distinguished officer, and by all reports humble.
[128] Ifland, Peter, “The History of the Sextant,” Lecture at the Physics Museum under the auspices of the Pro-Rector for Culture and the Committee for the Science Museum of The University of Coimbra, October 3, 2000, http://www.mat.uc.pt/~helios/Mestre/Novemb00/H61iflan.htm.

Figue 8.7. Astronomical Evolution at Sea: From Davis Quadrant to Sextant.[129] Thomas Harriot proposed a corrective to inherent difficulties of solar glare and parallax by outlining several designs for a back-staff, requiring the observer to read shadow and horizon, rather than ascertaining solar height by staring directly at the sun while simultaneously fixing the horizon. The Elizabethan mariner John Davis constructed such a device and published the details of its construction and use in his *The Seaman's Secrets* in 1594. The large end of the device (left) was held against the face while keeping one's back to the sun, while the observer simultaneously fixed the horizon and the shadow of the sun on small quadrant scale (right). The Davis Quadrant or English back-staff became the predominate marine celestial observation device for over a century, until it was replaced with Hadley's optical octant and its successor, the sextant (shown on the right). These instruments allowed direct viewing with their reflecting mirrors and telescope, enabling readings of stellar and lunar positions too faint to cast a shadow on the back-staff.

Scientific Prizes and Longitude – Theories and Clock Makers

Resolving longitude determination at sea was the single largest remaining problem facing early modern navigators. By the dawn of the eighteenth century, three major approaches were under serious consideration: lunar parallax, clock time, and magnetic variation.[130] Despite competing and erroneous theories trying to link longitude and magnetic deviation (Gilbert and Sarpi), a number of earlier natural philosophers and astronomers had noted the relationship between solar time and the globe.[131] Theories on using accurate clocks to ascertain longitude were not uncommon since at least 1522 when Gemma Frisius of Louvain, who served the

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[129] "Nautical Instruments Celestial Navigation," Dehilster.info, http://www.dehilster.info/navigational_instruments/1734_w._garner_davis_quadrant_backstaff.php and Ifland, Peter, "The History of the Sextant," Lecture at the Physics Museum under the auspices of the Pro-Rector for Culture and the Committee for the Science Museum of The University of Coimbra, October 3, 2000, http://www.mat.uc.pt/~helios/Mestre/Novemb00/H61iflan.htm.

[130] Taylor, *Haven-Finding*, 247, notes a variation of the magnetic approach. She notes that in 1602 Gilbert, Thomas Blunderville, Edward Wright, and Henry Briggs were trying to use magnetic dip or inclination, rather than magnetic variation to ascertain latitude. It was Gilbert's dream to link magnetic variation and longitude.

[131] Heilbron, John, *Galileo*, 96-99.

Spanish king, postulated that since the earth measures 360° of longitude and spins in twenty-four hours; longitude will differ from a known point of departure by comparing astronomical noon with home port noon and adding one degree longitude westward for each four minute time difference.[132] However, even well-made sixteenth century clocks lost fifteen minutes daily and the unwieldy astrolabe was the primary time keeper even on land; even by the eighteenth century state of the art clocks would distort time in different temperature, moisture, and climactic conditions. The solution to this problem seemed to be in the stars. The evolving clockwork metaphor for the heavens combined with astronomical telescopes excited much speculation in this regard.

As David Waters notes, "so far as Jacobean navigators were concerned, the immediate result of the application of the telescope to astronomy was Galileo's proposition for finding longitude by the four [known] satellites of Jupiter."[133] Galileo's attempt in this regard is well documented. Shortly after announcing his monumental discovery of the Jovian moons, he went about trying to use their eclipses and phases as a clock, despite Kepler's admonition.[134] These and other attempts would fail, but the attempt to reconcile a navigation problem as an astronomical one is illustrative. In 1714 Parliament would offer a sizeable reward and research grants in response to the 1707 fleet disaster off the Scilly Isles.[135] This prize would be mirrored

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[132] Taylor, *Haven-Finding*, 245-246, notes that Richard Eden translated Frisius's theory into English in 1555 and that William Borough possibly tested the theory with the clocks of his day.

[133] Waters, 299.

Taylor, *Haven-Finding*, 248, "Galileo at once realized that their eclipses [his four Jovian moons], taking place almost nightly, would serve far better than the eclipses of the Moon for the determination of longitude."

[134] Heilbron, 166. See also pgs. 235-236: By 1617 he was negotiating with the Tuscan ambassador, expensive terms to Spanish King Philip III in 1617-1620, headgear developed (*celatone*) – (Pg. 346) tries again around 1630, rebuffed; 1635 tries for Dutch prize – no royalty agreements – gifted it to them as he had gifted Venice his telescope – had to turn down Dutch visit and gold chain gift due to his house arrest.

[135] Sobel, Chapter 2, recounts the disaster of October 22, 1707, when Sir Cloudesley Shovell's fleet of warships returning from the Mediterranean station foundered on French rocks when entering the channel with the loss of four ships, almost two thousand men, and their admiral. Inaccurately fixing longitude at sea and of landmarks on Admiralty charts, coupled with Shovell's rejection of a sailor's position warnings caused the disaster and prompted action by Parliament.

by French and Dutch equivalents across the Channel as Western Europe's best clock makers scrambled to create a reliable and replicable chronometer. The dead-end of Jovian (lunar) observations and the complicated lunar distance method (made possible by the tables produced by the German astronomer and mapmaker Tobias Mayer) would both be finally eclipsed by John Harrison's chronometers in 1762.[136] E.G.R. Taylor notes that "With [John] Hadley [octant for assessing latitude accurately] and Harrison [accurate chronometers for fixing longitude] what may be termed the pre-scientific age of navigation was brought to a close."[137] With accurate celestial instruments, abundant celestial data provided by the Royal Observatory in comprehensive almanacs on the French model, and accurate clocks reliably fixed to Greenwich Mean Time (GMT), England's merchant and naval fleets could more reliably and safely transverse the globe.[138] When these advances were combined with better measuring systems; mathematical conversion tables generated by logarithmic analysis; new meteorological and hydrographic charts; and reliable sounding, shoal, and coast data provided by the Admiralty

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Roger, *Command*, 172, notes that "Shovell was perhaps the only truly popular English admiral of the age, beloved by officers and men, respected by politicians of all parties. His death caused a profound shock, and led in due course to the 1714 Longitude Act." This despite what the author calls "remarkably careless navigation."

Herman, 260-261, notes that George Anson's problems rounding Cape Horn during the War of Jenkin's Ear added impetus to the quest upon his triumphat return in 1744. His subsequent ascedence at the Admiralty provided him the platform to test propsals with naval vessels and officers and he supported both astronomical and mechanical solutions. See footnote on Tobias Mayer's lunar tables below.

[136] Taylor, *Haven-Finding*, 245-248.

[137] Ibid, 263.

[138] Ibid, 243, notes that as with the construction of their Paris observatory, the French produced the first comprehensive celestial almanac for mariners in 1678/9 – the *Connoissance des Temps*. These tables centered their Prime Meridian on Paris, not Greenwich. The Almanac was taken over by the *Bureau de Longitudes* in 1798.

Ifland, 1, summarizes the essential components required for precision celestial mathematical navigation that were now in place:

(1) "An Almanac prepared by the astronomers to forecast precisely where the heavenly bodies, the sun, moon planets and selected navigational stars, are going to be, hour by hour, years into the future, relative to the observatory that prepared the almanac, Greenwich, England in modern times.

(2) A chronometer or some other means of telling the time back at the observatory that was the reference point for the data in the almanac,

(3) Accurate charts so that navigators can establish their position in latitude and longitude or in reference to landmasses or the hazards of rocks and shoals.

(4) A quick and easy mathematical method for reducing the data from their celestial observations to a position on the chart

(5) An angle-measuring instrument, a sextant, to measure the angle of the celestial body above a horizontal line of reference."

(eventually by the Hydrographic Office), England had effectively shrunk the world.[139] All its oceans were accessible. With the explorations of Captain Cook in the Pacific in the Eighteenth century, the picture would become largely complete. Cook carried Halley's charts and Harrison's chronometers with him and was able to reliably chart the vast region, expanding the centuries old navigational canon he inherited.[140] However, this marriage of natural science and England's maritime ambitions would have repercussions for the exercise of both. Over the course of the sixteenth century England had transformed from a medieval kingdom ruled by a landed aristocracy to a modern maritime imperial power which had moved from technological laggard to innovator. In order to expand its trade, protect its dominion, and guard its new secrets, the new United Kingdom and its newly organized scientific and maritime communities would have transitions to endure as they careened into modernity.

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[139] George III appointed the first Hydrographer to the Admiralty, Alexander Dalrymple, in 1795. But as the example of Samuel Pepys commissioning Edmund Halley in 1686 to chart the Channel illustrates, the Royal Navy had long been in the business of surveying and disseminating cartographic data.

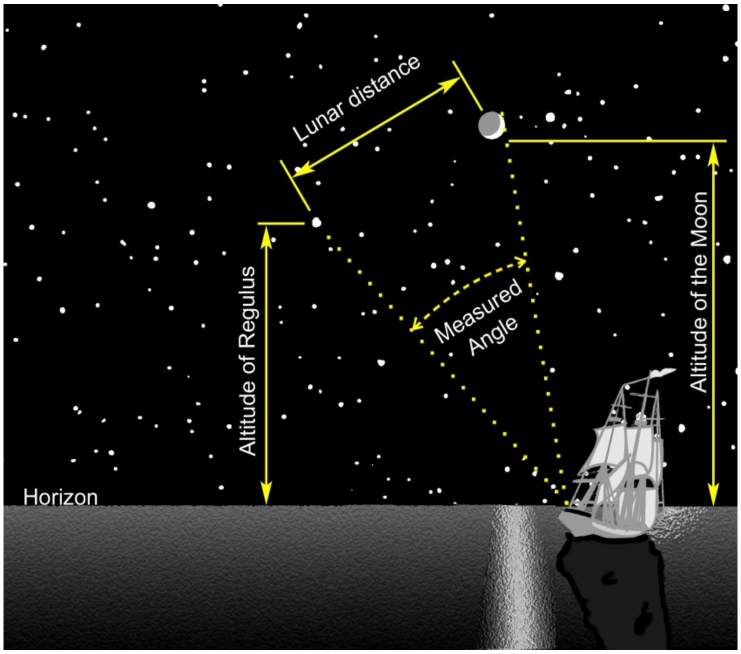
[140] Sobel, 166, notes that Cook took a copy of Harrison's prize winning H-4 chronometer on his second journey in 1772 because the Board of Longitude was still examining the original device and being excessively parsimonious in awarding the balance of the prize. Cook had nothing but praise for the chronometer.

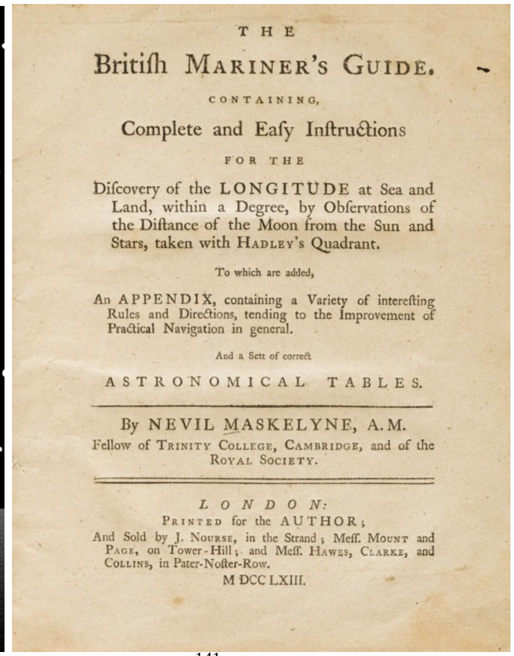
Herman, 261, notes that before this journey, Cook, among other naval officers, had successfully demonstrated the accuracy of the lunar tables created by the German mathematician Tobias Mayer and submitted in 1757 to the First Lord of the Admiralty George Anson. Mayer was the first to receive prize money from the Longitude Board in 1767. However his method required precise tables, an accurate sextant, and hours of calculation.

Sobel, 114, notes that Anson also used Captain John Campbell to test the tables even during the Seven Year's War and that Tobias Meyer's widow was given his £3,000 award five years after his early death. His Swiss mathematician colleague Euler received £300.

Robson, 69, 184, notes that the innovator of the sextant, was Captain (later Admiral) John Campbell and the famous instrument maker John Bird. Campbell was the man who introduced James Cook to the Royal Society.

Cambell (see footnote 127) was an accomplished scientific navigator and the innovator of the sextant.





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And a Sett of correct

ASTRONOMICAL TABLES.

By NEVIL MASKELYNE, A.M.

Fellow of TRINITY COLLEGE, CAMBRIDGE, and of the ROYAL SOCIETY.

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M DCC LXIII.

Figure 8.8. The Lunar Distance Method: An Astronomical Clock and Longitude.[141] The quick nightly movement of the moon (27.3 day orbit - the sidereal month) of 13.2 degrees per day or half a degree an hour (roughly its own diameter), is observed with respect to the background stars and the Sun. A sextant is used to measures the angle between the moon and another body. After correcting for parallax error, the observer searches a table of lunar distances correlated to Greenwich Mean Time (GMT). He then calculates longitude by contrasting local time and GMT. In order to perform the calculations one turned to the *The British Mariner's Guide*, 1763 (right).[142] Tobias Mayer's lunar distance tables, generated with the aid of Leonhard Euler's formulas, formed the basis for ascertaining time at sea using the Lunar Distance Method. The Astronomer Royal James Bradely, the successor of Edmund Halley, turned the attention of the Greenwich Observatory to confirming their accuracy. Working with Hadley's sextant in St. Helena, Nevil Maskelyne refined the method and presented it in his guide as an astronomical alternative to the novel, but easier, clock method of Harrison. The method required three to four hours of calculations and painstakingly prepared lunar almanacs without the Guide, but was still laborious with it. As with all celestial observation, it was also limited by weather.

Salomon's House and the State: Collision and Confluence

As we addressed at length in Chapter 6, Bacon's ideal of open research and public demonstration presented in his Salomon house and partially realized in the Royal Society, from the onset was subordinate to the exigencies of national and mercantile competition. It was also subject to institutional and bureaucratic effects within the nascent bodies. Although there was still a great deal of open technological and theoretical transfer across Europe's borders regarding the evolving maritime canon, all the nations engaged in the oceanic and imperial projects

[141] Image from Wikimedia.com, https://commons.wikimedia.org/wiki/File:Lunars-star-map.jpg.
[142] "Time to solve longitude: The lunar distance method," Royal Museum Greenwich, Rmg.co.uk, http://www.rmg.co.uk/discover/behind-the-scenes/blog/time-solve-longitude-lunar-distance-method.

attempted to secret those innovative details which they thought gave them national or competitive advantage. In this period of the birth of modern scientific institutions, to include journals, academies, public demonstration, and mass data accumulation; we also can glimpse the modern obsession with restricting information not just on the movement and numbers of military forces, but on the fruits of scientific research as well. For it was in this period, especially at sea, where scientific prowess became inexorably wedded to military power.

We noted the case of William Perry's 1665 manuscript on shipbuilding and Lord Brouncker's decision to 'classify' it as secret.[143] At the close of the seventeenth century, the Royal Society was becoming the clearinghouse for England's scientific research and in particular, research flowing in from the maritime project.[144] An extensive archive of these documents is maintained by the Royal Society and was made available on microfiche in 1992. The *Collections from the Royal Society: The Early Letters and Classified Papers, 1660-1740* reveals the extent and scope of the data the Royal Society handled, much of it maritime in nature. The Early Letters constitute the first fourteen microfiche reels and reveal the early infighting, intellectual disputes, and growing pains of the early institution. They also catalogue the substantial foreign input into the Society. The Classified Papers constitute reels 15 to 23 and comprise 25 volumes of papers. Mathematically breakthroughs are covered in the first volume (I). Other volumes are dedicated to optics (II); hydrology and meteorology (IV-VI); shipbuilding, geography, navigation, and voyages (VII); astronomy (VIII); and magnetism (IX). There is also a volume dedicated to Edmund Halley's papers (XXI). It is important to note that the expression 'classified' is used here in its organizational sense and not in the modern sense of

[143] Macrakis, 191.
[144] Feingold, Mordechai, Introduction to Collections from the Royal Society, *The Early Letters and Classified Papers, 1660-1740*, Project Editor, Paul Kesaris, Bethesda, MD: University Publications of America (microfilm project), 1992, vi, adds that is was a clearinghouse for foreign correspondence from continental researchers.

restricted. However, Mordechai Feingold, in his introduction to the project, notes that many of these papers were never published in *Philosophical Transactions*.[145] In part, these records are examples of the global call for data espoused by Secretary Oldenburg, and which we have reviewed from Boyle and Auzout in the first publication of the Society. We also see the birth of scientific editing to include not just content, but the excise of personal asides and attacks.[146] Feingold adds that these archives also constituted a storehouse for later priority claims.[147]

The charter of 1662 which Charles II granted to the Royal Society specifically allowed the members "to correspond freely with savants on the continent, and to publish free of censorship, all works pertaining to natural knowledge."[148] Early crises spurred by the lack of Royal financial support, the 1665 plague, the Great Fire a year later, member infighting, and professional jealousies from the Universities and the Royal College of Physicians, helped create an institutional structure which in part restricted the flow of information in order to quell disputes and avoid subjecting the Society to ridicule by the premature publication of suspect or controversial hypothesizes. Regardless, we can see in these papers detailed accounts of the hydrographic data accumulation so desperately needed at the end of the seventeenth century. Once again Lord Sandwich appears proposing "to sound the depth of the sea in the Bay of Biscay and the Straights [of Magellan] at full sea or low water, without a line, … Take[ing] a globe of some wood having a hook fastened to it …" in 1661, several years before Auzout's and

[145] Feingold, ix.
[146] Ibid, xiv-xv, Oldenburg even edited Newton and Halley for generalized derisive comments (Newton on naturalists) and *ad hominem* attacks (Halley on Seth Ward).
[147] Ibid, x-xii, cites examples of Boyle and Huygens. The Royal Society achieved its desire to become the arbiter of issues of priority in 1713 when Queen Anne ordered that all patent applications receive prior Royal Society approval. They were overwhelmed in this task in 1714 when Parliament authorized the Longitude prize.
[148] Ibid, v.

Boyle's instructions were published or Hooke's devices described.[149] We have his astronomical observations from that voyage in Volume VIII as well.[150] The diarist and Fellow of the Royal Society (FRS) John Evelyn, although neither a mariner nor a naval officer, provides a detailed dictation from a long-term resident of the geopolitically critical island of Tenerife in the Canaries astride the Atlantic gyre westward. [151] We also find papers describing Iceland (Volume VII (1), paper #9), the exact length of the Mediterranean (Volume VII (1), paper #46), and detailed accounts of early trips to Constantinople by the Reverend Thomas Smith (Volume VII (1), paper #51), which he later published in *Miscellanea Curiosa: Containing a Collection of Curious Travels, Voyages, and Natural Histories, As they have been Delivered to the Royal Society*. Vol. III. London: Jeffrey Wale, 1707. In the Mediterranean paper we find echoes of the overriding navigational issue of the day and the immensity of the challenge. Its anonymous author quips that "the Discovery of Longitude is the Philosophers Stone in Mathematics."[152]

Further hydrographic and cartographic exploits of the early members of the Royal Society are described by Richard Williams who gives a firsthand detailed account of Sir John Narborough's 1669 survey of the Straight of Magellan (Volume VII (1), paper #32). During the epic journey of the *Sweepstakes*, Williams was able to document that Narborough's journey had "demonstrated the falsity of the accredited wisdom that the wind and currents would prevent any

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[149] Montague, Edward, "Propositions of some Expts. [Experiments] to be made by Ld. S. [Lord Sandwich] in his present voyages to the Straights and into Portugal, 1661 in June," *The Early Letters and Classified Papers, 1660-1740*, Reel 16, Volume VII (1), paper #2.
[150] Montague, Edward, "Observations in his Voyage to Portugal," *The Early Letters and Classified Papers, 1660-1740*, Reel 16, Volume VIII (1), paper #5.
[151] Evelyn, John, "An exact Relation of Tenariff [Tenerife], dictated by Mr. Clappham to Mr. Evelyn," *The Early Letters and Classified Papers, 1660-1740*, Reel 16, Volume VII (1), paper #1.
Tenerife is the largest and most populous island of the seven Canary Islands
Fernandez-Armesto, *Before Columbus*, 179, the Canaries became a focus of the Elizabethan, Stewart and Restoration navies as they chased the elusive annual Spanish silver fleets.
[152] Anonymous, "For Rectifying the Straights or finding the exact length of the Mediterranean," *The Early Letters and Classified Papers, 1660-1740*, Reel 16, Volume VII (1), paper #46.

west to east passage."[153] The practical implications of Narborough's resulting chart and the discovery that two-way sailing was possible when crossing from the Atlantic into the Pacific around South America was monumental. Practical cartographic issues were also discussed in the second part of this volume; wherein we find two papers on spherical map construction and globe making (Volume VII (2), papers #15 and 16). This is a small sampling, but it demonstrates that the Royal Society early in the eighteenth century was the leading repository and editor of new maritime knowledge in the world.

Connections

As we observed in the last chapter, the scientific, navigation, and ship building advances of the seventeenth century were critical in pushing the northern Protestant maritime programs to the forefront of the endeavor. However, equally as important during this period, the Dutch and English developed proto-modern administrative bureaucracies to field enormous naval and trading fleets. Over the course of the century, they overcame the hitherto unimaginable monetary requirements of protracted seventeenth century naval warfare and created standing navies which professionalized and grew in technical competence with their new stability and public support as indispensable national assets. They developed financial institutions that created the enormous liquidity for both naval warfare and sustained global trade. They also pioneered devices for managing risk, diversifying losses, and mobilizing yet more capital as success overseas produced an upward spiral of ambition and productivity. And most significantly, the maritime trade classes, neither landed aristocracy nor peasants nor craftsmen, moved to occupy a position of central importance in both the Dutch Republic and the various

[153] Williams, Richard, "A Voyage of ye [the] Sweepstake to the Straights of Magellan (Captn. [Captain] Norbrow [Sir John Narborough], Commander) in 1669," *The Early Letters and Classified Papers, 1660-1740*, Reel 16, Volume VII (1), paper #32.

English governments of the century. Both nations had embraced a national mythology linking domestic prosperity and international security to the sea.[154] Maritime ambitions were shaping these societies and especially in England, the state-makers were simultaneously capitalizing on oceanic prowess, spurring intellectual innovation, and creating institutions to support their maritime ambitions that were reordering the social hierarchy and changing the agrarian aristocratic medieval state into the modern administrative state. But unlike in France and Spain, the Dutch and English states were more representative in the fact that they were catering to the needs of this growing merchant and financial middle class associated with long-distance overseas trade. Each was developing a national market tied to global trade.

That the two great northern Protestant maritime powers would clash was perhaps inevitable. However these conflicts among other things, helped resolve a host of global norms which hitherto had never needed contemplation. The modern laws of the sea and of international trade, finance, insurance, and salvage can be glimpsed in the Anglo-Dutch struggle. These struggles of course produced naval tactics that would predominate for almost two centuries until Nelson smashed the line of battle paradigm at Trafalgar.[155] But it is the legal and financial

[154] Rodgers, P.G., 14, notes "that each country [recently experienced] the rise of powerful wealthy middle-class, its fortunes based on trade and commerce, whose aspirations soon brought it into conflict with the older aristocratic class whose fortunes were founded on land ownership."

[155] Adkins, Roy, *Nelson's Trafalgar: The Battle that Changed the World,* 54-58, At Trafalgar, Lord Nelson turned the line of battle paradigm on its head. Recognizing that his force was smaller than that of his combined Franco-Spanish opponents, he planned an assault in two columns perpendicular to the enemy battle line which aimed at both breaking that line and creating a pell-mell melee battle reminiscent of the late Renaissance, albeit with modern heavily armed battleships. He hoped to cut off the allied vanguard from the battle and concentrate his force against portions of the enemy center and rear and bludgeon their ships with teams of attacking vessels. He knew his crews and officers were more experienced from years on blockade service, that their gunnery was better, and that the French preference for aiming at rigging would allow his column to survive their mile long creep toward the broadsides of the enemy. He gave his commanders great flexibility in executing his strategic intent and charged them long before the battle was engaged with a simple directive, "in case signals can neither be seen [n]or perfectly understood, no captain can do very wrong if he places his ship alongside that of an enemy." Like the old naval commanders predating line of battle, Nelson's job as admiral was complete after he devised his attack, briefed his Captains, engaged the enemy and unleashed his ships. (100-101)

Tilley, John A., *The British Navy and the American Revolution*, notes that the limitations of line of battle strategy had been recognized for years before Trafalgar and that a radical solution was germinating after Nelson watched Rodney's fortuitous exploitation of the weather generated gap in de Grasse's line at the 1782 Battle of the legacies from this period which still undergird our modern system and which owe their paternity to the maritime project. Maritime exigencies were shaping society as it evolved towards modernity in England, and the peculiarities of English society were manifesting themselves in its unique maritime culture.

At the same time England was institutionalizing modern science and applying much of its initial discoveries directly to the maritime program. Hadley and Harrison may have brought the pre-scientific age of navigation to a close as Taylor claims, but their efforts were merely the capstone of England's two century race to first emulate and then surpass its continental rivals. It is possible to argue that Bacon's scientific method of inductive reasoning has been over applied within the realms of Western thought thereby resulting in the obfuscation of certain avenues of discovering 'objective truth' in areas outside the physical sciences. However this argument is irresolvable. We can however state that modernity and its debt to science have deep English roots. The agrarian England of the Middle Ages was supplanted by the modern maritime trading state and this complicated successor required a more accurate understanding of the natural world.

As navigation, shipbuilding, sailing rigs, ordnance production, and logistics grew more complicated; we see the emergence of the intensely interconnected modern society. The central conceit of John Masefield's poem *Sea Fever*, "And all I ask is a tall ship and a star to steer her by;" was no longer possible. To sail by that star you now needed a refined optics and instrument making industry; observatories that could assemble hundreds of thousands of meticulous celestial fixes, project their future locations anywhere in the world each day, and catalogue them in annual almanacs; mathematicians to reduce your observations to programmable data; accurate

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Saints. Other attempts were also made by the French Admiral Sufrin in India to concentrate force on parts of enemy line rather than along its whole length.

Nelson's decision at the Battle of Cape Saint Vincent, 1797, to break the line and lead an attack on the *San Jose* is one more indicator that Nelson had for a long time contemplated radical changes to the seventeenth century line of battle paradigm.

charts detailing hazards, currents, tides, winds, and magnetic variations; and a sophisticated logistics operation to build, rig, and provision your ship. By the dawn of the eighteenth century the maritime endeavor was an enormous undertaking and an integrated economic and social milieu that dwarfed the entire economic and intellectual output of medieval England. The English world had changed and it had changed at sea.

CHAPTER 9.

The Royal Navy and the Foundations of the Modern State: Global Wars and Staying Power from the War of Spanish Succession to the Seven Years' War

Although the Glorious Revolution resolved with finality the question of monarchal or Parliamentary supremacy in Great Britain, with the latter's ascendance, the price Parliament had to pay for this victory was not cheap.[1] Over the following quarter century enormous amounts of English blood and treasure funded William's *La cause commune*.[2] Following the Hanoverian succession, and with it the assumption of continental territorial obligations, successive English governments would establish a relatively consistent policy of fighting rising hegemonic powers on the continent for the next three centuries. The maritime project would provide the main tools for enacting this policy. Global trade provided England the gold it used to cajole and succor its allies, while her navy enabled strength projection into every ocean and onto every accessible inhabited coast, and it provided the evolving power to choke the global trade of her enemies, while at the same time securing her own trade and the safety of her home islands.

Even after the deaths of William III and James II's childless daughter Queen Mary II and Queen Anne, whose children did not survive her, England's political class could not escape involvement on the continent. In order to secure protestant succession, Parliament in 1701 had convinced King William III to support the Act of Succession which bypassed twenty Catholics in

[1] Israel, 10, notes that "the Revolution did make Parliament supreme: and it did transform England into a religiously and intellectually pluralistic society." Despite revisionist critiques of the Whig view, this Revolution of 1688 "was the crucial turning-point in England's constitutional development." It was the point England rejected absolute monarchy and it did so shortly after Denmark and Sweden chose the alternative path.

[2] Ibid, 22-23, observes that upon entering the Nine Years War in 1689, "England was transformed from being one of the most lightly taxed countries in Europe to being the second most heavily taxed after the Dutch Republic." Royal annual revenues jumped from less than £2 million prior to 1689 to £5-6 million from 1689 to 1702. He adds, 31, "The Glorious Revolution created a real balance of power in Europe … [and] replaced French dominance with general deadlock."

William III's successor Queen Anne and the Duke of Marlborough (John Churchill) continued William's struggle on the continent against the hegemonic ambitions of Louis XIV as part of the War of Spanish Succession (1701 to 1714) and in North America under the historical title of Queen Anne's War, fought between 1702 and 1714.

the line of succession in order to rest firmly of the Protestant Sophia, Electress of Hanover.[3] However, first we will return to William III.

Unlike his immediate Stuart predecessors, the Prince of Orange was not an earnest advocate of England's navy. He was a soldier and his family history aligned his interests not with the maritime trading states of Holland and Zealand, but with the agrarian Dutch and their continental frontiers.[4] However, William was a man of strategic foresight and his alliance against France, lacking interior lines, left Spain and Savoy exposed to French aggression. In order to shore up his alliance he determined that naval control of the Western Mediterranean was imperative.[5] Early Dutch and English losses in this theater led the English and Dutch to decide that they needed a modern base close by which could supply, equip, and refit their fleets. They set about modernizing the dockyards in Spain's Atlantic port of Cadiz. The erstwhile students and subjects of Spain were now propping up their weaker ally and trying to modernize its maritime logistics infrastructure, which was the underpinning of their own naval success. A success marked by a century of Spanish wrecks strewn across the Channel and the North Sea.

We will return to the naval dockyard at Cadiz below, but these wars against France also witnessed several naval innovations. The French invented the bomb ketch, a ship used to house large siege mortars whose most practical function was bombarding cities. The French devastated Genoa in 1684 using such ships. This disturbing modern practice of terrorizing civilian population centers with long distance bombardment was condemned by all of Europe and then

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[3] Barone, 224, notes the Act of Succession was paired with the Act of Settlement which "required that the [English] monarch be a communicating member of the Church of England." The Act of Succession also prohibited the new Hanoverian sovereigns from appointing or removing judges; a power abused by Charles II and James II, but never exercised by either William III or Anne.

[4] Mahan, Alfred T., *The Influence of Sea Power upon History, 1660-1783*, 191, "The head of the opposition to Louis XIV was William III, and his tastes being military rather than naval combined with the direction of Louis' policy to make the active war [of the League of Augsburg] continental rather than maritime."

[5] Rodgers, *Command*, 152.

quickly emulated.[6] The French also pioneered the use of large privateering squadrons designed to overwhelm any convoy escorts assigned to them.[7] Having abandoned the battle fleet strategy of Colbert (*guerre d'escadre*), the comte de Pontchartrain turned French naval strategy towards *course de guerre*.[8] These tactics foreshadowed those of Donitz's U-boat wolf packs, especially as they were motivated more for the disruptive impact they would wreck on the enemy's economy, rather than on the profit motives that launched the Elizabethan privateer fleets, financed not by the state, but mostly by private investors. The efficacy of this strategy can be endlessly argued, but financial exhaustion on both sides ended the conflict in 1697, and these disruptions to commerce obviously played their part.[9]

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[6] Rodgers, *Command*, 155-156, the Allies, after failing in their amphibious invasion attempts of France, bombarded the privateering bases of St. Malo in November 1693 and Dunkirk in September 1694. They also attacked the commercial port cities of Dieppe and Le Havre. John Evelyn noted that stopping privateers at sea was more palatable to the public than this behavior "totally averse to humanity, and especially to Christianity."

[7] Dull, 28-29, notes that the French naval budget for the years 1691 through 1693 was 100 million livres or 33 million per year. In 1694 Louis XIV cut this budget to about 24 million livres and started loaning out his ships for privateering exercises. One state-private venture included seven ships of the line, captured Cartagena, and grossed 7.5 million livres plunder.

Rodgers, *Command*, 158, these squadrons were notable not just for their size, but their composition. Unlike the private raiders of previous wars, these squadrons were either entirely made up of French naval vessels or a mix of both naval and private vessels under French naval command.

Herman, 226-227, inspired by Louis XIV's great military engineer Sébastien Le Prestre de Vauban, the French saw Brest as the ideal geographic interruption point for inbound Dutch and English global commerce [just as Dunkirk was for the North Sea and Channel carrying trades]. Unlike the raids of Hawkins and Drake, this policy would use large naval forces of the crown, organized centrally, and operating continually out of Brest, Rochefort, and Toulon – "involving hundreds of heavily armed navy ships, in addition to privateers." Herman regards the results as "spectacular," citing 3,500 prizes versus only 500 before the policy was implemented in 1695.

[8] Rodgers, *Command*, 148. Also the comte de Maurepas (1687), he was the successor of Colbert's son, the Marquis de Seignelay, who had taken over from his father upon his death in 1683.

[9] Dull, 29, notes that "French … *guerre de course* became a model for subsequent navies too weak to risk fleet encounters, but it was adopted not for strategic reasons but to save money."

Mahan is the most noted advocate of blockade and fleet battle strategy as the only effective national use of sea power. 190-198, He notes that Anne Hilarion de Costentin, comte de Tourville, the victor of the 1690 Battle of Beachy Head (*Victoire de Béveziers*), after succeeding with his daring attack against a Dutch and English fleet twice his size at the battle of the Battles of Barfleur and La Hogue (29 May 1692), had his fleet savaged by Allied fireships while they anchored for repairs at Cherbourg. This victory turned to defeat altered French naval strategy even though Trouville's loss of 15 ships [and all his transports] "was all out of proportions to the results." Tourville sailed the following year taking/disabling the 400 ship merchant Smyrna convoy and caused financial panic in London. Mahan contends that the "decay of the French navy was not due to any one defeat, but to the exhaustion of France and the great cost of the continental war." He minimizes the impact of French commerce raiding and faults national French naval support and unrealistic naval expectations for their negotiated peace.

Herman, 218-220, at Beachy Head in 1690 Tourville had succeeded in destroying fifteen Allied ships under Lord Torrington (Admiral Herbert) while losing none, he drove the Dutch fleet out of the war, and he gained control

War returned to Europe and the globe in earnest when Louis XIV repudiated his treaty obligations and tried to absorb the entirety of the Spanish patrimony into his sphere. Rodger notes that, unlike the Austrian Hapsburgs, for the English and the Dutch, "the War of Spanish Succession (1703-1714) was about access to the Spanish Empire, not Spain itself."[10] It also continued the century-long English progression in its ability to sustain battle fleets at sea far abroad, to stay on station throughout the seasons, and to operate out of remote bases. For the Royal Navy, the wars of the late seventeenth and eighteenth centuries were institution building exercises as well as deadly combat. The material benefits of the war for England (Gibraltar in 1704 and Minorca in 1708), and alliance with Portugal ensured that England would have the bases it needed to control the Western Mediterranean and to provision in the Atlantic.[11] It also gave them control of what would become eastern Canada and stronger positions in the Caribbean. Coupled with these Caribbean acquisitions, the British gained the *Asiento* or right to trade slaves to Spain's colonies in the Americas.[12] English trade had expanded greatly during the war, growing not just its economic muscle, but the size of its maritime community and pool of available seamen. However, the ensuing explosion in sugar production and the resulting

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of the English Channel. This 'nightmare scenario' for England was only remedied by news of William's victory in Ireland over James at the Battle of Boyne. Lacking a deep water port from Brest to Dunkirk, the French fleet had to abandon the Channel; a geographic reality that would shape their naval strategy for the next two centuries. Torrington argued that his withdrawal at Beachy Head, although condemning the Dutch, had kept his fleet intact and that this 'fleet in being' was what staved off French invasion. This policy would become English naval canon. The first manifestation of which was the overwhelmingly superior fleet which Tourville was ordered to attack in 1692.

[10] Rodgers, *Command*, 164.

Dull, 30, notes that the Spanish reasonably wanted to keep their empire intact and that since the Austrian Hapsburgs and their Emperor Leopold had no navy to protect the Spanish dominions, it was logical for Charles II to bequeath his titles to Louis' grandson the Duke of Anjou and later Phillip V. Regardless of the dynastic imperatives facing the Bourbons and the Hapsburgs, the English and Dutch settled their gaze seaward.

[11] Dull, 34, notes that "the acquisition of Gibraltar and [Port Mahón] Minorca, where dockyards where built, permitted Britain to intervene in the Mediterranean whenever it wished."

Roger, Command, 167, references the 1703 Methuen Treaties and notes that they became "an essential component of eighteenth-century Britain's prosperity." Gold discoveries in the 1690s in Brazil were transported on Royal Navy warships whose captains charged 'freight' as allowed by the navy.

[12] Dull, 42, The Treaty of Utrecht, signed in 1713 and later modified in 1716, gave the South Sea Company of Britain the right to provide 4,800 slaves annually for the next thirty years.

tenfold increase in the African slave trade over the century dramatically increased that upward trajectory and with it, British overseas investment.[13] We will return to economic importance of the English South Sea Company and British trading rights and its ensuing disputes in Spanish America shortly, but it is important to emphasize that this war was a global war, in large part fought by one side with maritime trade objectives, which they largely achieved.

However, the war was not a complete success for England. The depredations of the French privateer fleets although not as bad as in the previous war were extraordinarily expensive.[14] Despite the victories of the Duke of Marlborough and Prince Eugene of Savoy in the Low Countries and central Germany, the public tired of the financial stress and the loss of life.[15] By 1715, King Louis XIV, the Emperor Leopold, and Queen Anne were all dead. As power on the continent shifted and Austria rose, Great Britain realigned in opposition. The great-grandson of James I, George, Elector of Hanover, assumed the throne of Great Britain,

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[13] Herman, 236-238, notes that the sugar boom "replaced gold and silver as the wealth of the Indies." This boom was growing before the War of Spanish Succession and Herman notes that by 1660 sugar imports surpassed all other cumulative imports to England. Sugar became the first commodity imported to Britain and exported as a value added product (rum and molasses). French Martinique and Guadeloupe, Dutch Curacao and Aruba, and the English possessions of Jamaica, Antigua, Barbados, St. Kitts, and Nevis, drove this market and became a charnel house for African slaves. Herman contends that without sugar the Atlantic slave trade would have withered, instead the number of people sold yearly jumped from 7,000 in 1650 to almost 70,000 in 1750.

[14] Herman, 239, notes merchant losses from 1702 to 1712 were half of the total losses during William III's war. He attributes this improvement to improving navy convoy tactics and a large frigate building program at the start of the century which doubled the number (from 26 in 1690) by 1710, and doubled that number again to over 100 by 1750. The combination of these cruisers with foreign operating bases and distinct patrolling grounds safeguarded trade.

[15] Roger, Command, 175, notes that inevitably … privateers presented the main threat to allied trade.

Mahan, 229-230, again disagrees and cites statistics from the House of Lords regarding the five year period ending in 1707. England lost 30 warships and 1146 merchants, of which 300 were retaken. France lost 80 warships, 1346 merchants, and 175 privateers. He notes that the majority of French warships were privateering when lost. Although damaging, he contends the French privateer war did not affect the war's outcome or shift sea power away from Great Britain.

Roger, Command, 177, concedes that it was not at all clear that the new privateer effort was profitable economically or militarily. English trade was more robust than in the 1690s and English trade protection was improving. The 1708 Cruizers [sic] and Convoys Act assigned forty-three Royal Navy ships (half of its 3rd to 6th rates) from the Admiralty to home stations to act as cruising (hunter) squadrons. Rodger also doubts that this proto-Coast Guard was effective.

Herman, 227-228, adds the Cruiser Act, its hunter squadrons, faster frigates, and the bombardment of privateer ports would all prove ineffective. Only the maintenance of permanent fleets on station, with adequate infrastructure and logistical facilities, in the Mediterranean, the Caribbean, and North America, would eventually prove effective against French privateer squadrons.

united in 1707 by the Act of Union. George I had to quell a Jacobite rebellion shortly after his ascension, but after siding against Sweden in the Baltic War, he was able to preside over an extended period of peace, made possible by a prudent alliance with the regent to Louis XV, the Duke of Orléans.[16] Such brief periods of European peace were often shattered by the local territorial ambitions of one or more continental powers. However, the wealth and power being generated by the expanding oceanic maritime trade project added a new dynamic to these contests. Europe's diplomacy was no longer the lone purview of princes, priests, and parliaments. Merchants and trade investors had generated both domestic security and wealth for the populations of several Atlantic nations, and their interests could sway public opinion for war as effectively as kings and their counselors. This was especially true in mid-Eighteenth century Britain. Regardless of its shifting continental alliances, British maritime policy remained focused on expanding trade, deterring invasion with a large Channel fleet, and scouring the seas of pirates and privateers. Their success, much like the Iberian successes of earlier centuries incited both envy and in some cases, imitation.

After a long period of naval stagnation, both Spain and France revived their naval ambitions in order to both protect their colonial empires and to check Britain. Spain launched a consistent dockyard and ship building program to protect its imperial possessions and possibly tip the balance of power in a future alliance, but not to directly confront Britain for control of the

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[16] The Great Northern War (1700 to 1721) was fought between Tsar Peter I's coalition and the Swedish Empire. George I entered the coalition on behalf of Hanover in 1714 and Great Britain in 1717. The war replaced Swedish dominance of the Baltic with that of Russia. The death of Charles XII and defeat ended absolute rule in Sweden.

Roger, *Command*, 226-227, notes that the first two Hanoverian kings ruled Britain as a one-party state, excluding any Tory input and confiding only in Whig counselors. The continuing Jacobite claims from the heirs of James II and "a disloyal population and many enemies abroad," created a political milieu where George I and II "had little to depend on except the Navy. … Fear dictated a large fleet in home waters." He notes that James III, Queen Anne's half-brother would have ascended to her thrown if he had just renounced his Catholicism, as her Tory counselors advised.

Dull, 36-38, the Hanoverian peace (1721-1733) "was largely the product of the alliance between Britain and France." Even though England maintained her 'fleet in being,' Orléans demobilized much of Louis XIV's fleet.

Roger, *Command*, 232, notes in 1721 France had 31 ships, the same as in 1661. Spain had almost none.

seas.[17] The son of the comte de Pontchartrain who had turned French naval strategy towards *course de guerre*, the comte de Maurepas, appears to have been an advocate of building a navy capable of supporting extensive overseas trade by controlling the sea lines of communication. Rodgers notes, that upon his ascension as naval minister at the age of twenty-two in 1723, "French dockyards began building ships of the line."[18] These ships were almost all two-deckers. Their new 74-gun ships (what the English would call 3rd rates) were superior to the 60 and 70-gun ships that made up the bulk of the British fleet and were capable of long-range cruising even to the Far East.[19] However, by this time the British national myth of maritime destiny and its boundless public confidence in the superiority of its mariners was ascendant. Varied British mercantile interests demanded unlimited 'free trade', which was in reality unreciprocated British global access, a robust Royal Navy to ensure that access, and naval war against both threats to that trade (whether piratical or imperial) and opportune targets. The maritime community had done such an extraordinary job since the days of Elizabeth both protecting and enriching the realm, that the increasingly vocal public of this modernizing state was often solidly aligned with these interests. Neither Britain's 'elective monarchy' nor either of its emerging parliamentary parties could afford to ignore this opinion for long.

It is hard to find a candid contemporary or retrospective source that would claim that the British ever intended to honor the trading limits placed upon it by the Treaty of Utrecht. Although the treaty granted the British the right to supply only one trading ship a year and the *Asiento* limited the South Sea Company to an annual trade of 4,800 enslaved people to Spain's colonial possessions, the British used these concessions as a wedge to crack open and flood the

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[17] Rodger, *Command*, 232-233.
[18] Ibid, 233.
[19] Dull, 39.

underserved Spanish Caribbean market.[20] When the inevitable tensions caused by British smuggling and heavy handed Spanish coastal defenses resulted in the rough handling of a properly licensed British trader named Robert Jenkins, the maritime interests and their approving public prodded the Crown into launching a predatory maritime trade war in 1739.[21] The early victories of Vice-Admiral Edward Vernon in the Caribbean and Captain George Anson's arduous but spectacularly profitable four year Pacific expedition, did not compensate the nation for this disastrously expensive war and the destruction of Vernon's army outside the gates of Cartagena by malaria, yellow fever, and inept and divided leadership.[22] The War of Jenkin's Ear or *Guerra del Asiento* in Spain was launched for mercantile interest against a supposedly decaying Spanish target and although eventually subsumed into the War of Austrian Succession, its propagation displayed the increasing power of British maritime interests and their supporting public. However, what both the government and public learned was that Britain still did not possess the logistical and medical infrastructure to pursue large combined operations in either the Caribbean or the Mediterranean.[23]

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[20] Herman, 238, notes that Britain rapidly flouted its slave limits and was supplying almost half of the 70,000 slaves by 1750.

Rodger, *Command*, 234, is direct in claiming the treaty stipulations were "a concession which the British meant from the first to exploit to open up as extensive a commerce as they could manage in the teeth of Spanish legislation."

Dull, 42, notes from the onset of its receiving access that, "the South Sea Company used these privileges to engage in massive smuggling to the heavily regulated but undersupplied Spanish colonies of the Caribbean."

[21] Captain Robert Jenkins of the *Rebecca* lost his cargo and his ear to the Spanish *guarda-costa* in 1731. Although properly licensed, the Spanish seized many more smugglers. Regardless, Jenkin's innocence and his ear provided London's merchants with a *casus belli* and their public relations campaign eventually produced a declaration of war.

Rodger, *Command*, 236, notes that "thus the government was forced into a war with Spain."

[22] Robson, 58, the dysfunction in relations between navy and army contrasts with the remarkably good (and successful) combined arms operations in North America during the Seven Years' War. Robson notes the excellent relationship between General Amherst and Admiral Boscawen at the siege of Louisbourg. With some caveats, 77, 93, he notes the similar cooperation between General Wolfe and Admiral Saunders at Quebec. This pattern was repeated throughout the war at Montreal and at the recapture of St. Johns.

[23] Rodger, *Command*, 240, adds that the requirement of maintaining a large Channel fleet as a check on the French, whether neutral or overtly hostile, exacerbated this problem.

The ensuing War of Austrian Succession (1740 to 1748) although primarily fought on the continent, and for the monarchy, primarily on behalf of the Electorate of Hanover, still had major implications for Britain's maritime community.[24] Their influence extended well beyond naval affairs and their interests could trump military and political considerations to the detriment of the latter, but they could also prove beneficial to government when its limited resources were inadequate on station. Rodgers notes that British Caribbean planters resisted plans to take the enormously lucrative sugar colony of Saint Dominguez (Haiti) from the French for fear of increased domestic competition.[25] However, Dull notes that the British were able to defeat the French attempts to retake Nova Scotia due largely to the assistance provided by the Governor of Massachusetts, William Shirley. He raised 3,000 local troops and ships to seize Fort Louisbourg on Cape Breton to secure his colony's fishing industry and cripple his French competitors in a combined action with a small squadron from the Royal Navy.[26] Although the fortress was returned to France by the 1748 Treaty of Aix-la-Chapelle, it would again be the focus of a successful British attack in 1758 during the Seven Year's War. Its subsequent destruction would deprive the French of not just a strategic foothold to the entrance to the St. Lawrence and Canada, but of the local protection of its North Atlantic cod fishery. As we have noted, the link between active fisheries, the training of mariners, and the substance of a vigorous navy had been

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[24] In addition to incorporating the War of Jenkin's Ear, several other conflicts are included in this descriptor of the general European warfare of the period. They include: King George's War in British America, the First Carnatic War in India, the Jacobite rising of 1745 in Scotland, and the First and Second Silesian Wars.

Dull, 51, notes that George II personally commanded allied forces (British, Austrian, and Hanoverian) at the Battle of Dettingen in June 1743. Rodger, *Command*, 242, adds that "the Hanoverian connection, moreover, poisoned both diplomacy and domestic politics."

[25] Rodger, *Command*, 249.

[26] The fort, built by Maurepas was essential for protecting the cod fisheries and he demanded its return at the end of the War of Austrian Succession. He agreed to return the British Indian trading post of Madras for it.

Robson, 52, notes that the Governor of Massachusetts, William Shirley, had been petitioning for the attack since 1745 and that his colony largely paid for and manned the force.

Dull, 56-57, estimates that of France's total 40,000 to 60,000 mariners, 10,000 to 15,000 fished there.

Rodger, *Command*, 261, notes that even though French overseas trade increased after the setbacks of 1747, its number of mariners did not. A large amount of French trade was conducted from this point onward in the ships of other nations.

well established and accepted as common wisdom since Dr. Dee had written *The Perfect Arte of Navigation (1577)* during Elizabeth's reign.[27] French naval ambitions throughout the late eighteenth and early nineteenth centuries suffered from a lack of trained sailors, and it can be safely asserted that their expulsion from these fisheries exacerbated this condition.

In addition to the increasing importance of maritime interests coalescing public support to sway the ever more complex parliamentary government of modernizing Britain, these mid-century wars can viewed as the dawn of a reformation of sorts within the Royal Navy and its associated land based institutions.[28] A succession of very capable First Lords of the Admiralty launched a series of reforms starting in 1744.[29] All three of these men, Bedford, Sandwich, and Anson, were fellows of the Royal Society and seamen intent on improving navigation as we have seen specifically in the cases of Sandwich and Anson. But their reforms went beyond fostering scientific advances in general or for navigation in particular. Their most visible reform, although strategic, was increasingly possible due to advances in ship design, victualling, and navigation science. The idea was to deploy a substantial number of ships in a single force to permanently cruise in the western approaches to the English Channel and the Bay of Biscay. This 'Western Squadron' was initially proposed by Vernon, but by the mid-1740s had drawn the support of

[27] Dee, *The Perfect Arte of Navigation*, 9, 23, stresses the critical nature of the North Atlantic fisheries of the Newfoundland bank to both the health of the realm and to its merchants.

Smith, Charlotte Fell, 43-44, in assessing Dee's *Perfect Arte of Navigation*, notes that "Enough has been said of this book, perhaps to show that it is a remarkable contribution towards the history of the navy and the fishing industries in Britain." And she notes Dee's contention that his proposed "Petty Navy Royall, as apart from the Grand Navy Royall, will look after pirates, will protect our valuable fisheries, and generally serve us in better stead than four such forts as 'Callys [Calais] or Bulleyn [Boulogne].'"

[28] Herman, 240, in his examination of the naval component of the British maritime community notes that in the eighteenth century "the Admiralty would end up controlling no less than ten parliamentary boroughs. Thirty-eight naval officers were also members of Parliament." Merchant interests, often aligned with those of the Navy had far greater interest in Parliament.

[29] These reformist leaders included John Russell, the Duke of Bedford, FRS (1744-1748) and his two protégées, John Montagu, the 4th Earl of Sandwich, FRS (1748-1751, 1763, 1771-1782) and George Anson, 1st Baron Anson (of Soberton), FRS (1751-1756, 1757-1762).

Bedford, Sandwich, and Anson.[30] This Western Squadron was charged with intercepting French invasion fleets headed for Ireland or England, blockading the Atlantic ports, protecting outbound and inbound British merchant shipping, and disrupting enemy shipping.[31] In order to succeed it needed tactical innovations in signaling, greater flexibility afforded to its captains in battle, a large number of frigates acting as the eyes of the fleet, line of battle ships that could keep the sea year-round in most weather conditions, a logistical system that could re-provision the squadron at sea, and a well provisioned nearby port at Plymouth to refit and sustain the fleet.[32] The job of resolving these issues fell to Anson and his two primary deputies, Peter Warren and Edward Hawke. Warren as a Commodore had led the Royal Navy squadron at the capture of Louisbourg in 1745 and the younger Hawke would refine and implement the new Western squadron doctrine at the end of this war and throughout the next, and eventually train the leading officers of the Royal Navy's next generation.

Anson led the squadron of fourteen ships of the line to victory against a smaller French escort fleet at the First Battle of Cape Finisterre in May 1747. In October of that same year, when he and his second-in-command Warren were both ashore convalescing, Hawke defeated the French again at the Second Battle of Cape Finisterre. The resounding success of these actions, the losses to French merchant shipping, and the deprivation on French Caribbean islands, although military victories, were largely the product of large scale institutional reforms, administrative prowess, and advances in the British maritime sciences. Modern naval warfare

[30] Herman, 269, Edward Vernon proposed the idea as "the surest means for the defense for the kingdom [and] security of our commerce" from Portsmouth in August 1745 but was removed before he could implement it.

Rodger, *Command*, 252, notes that the idea was not completely new and that Drake had proposed something similar in the late sixteenth century. However it was not really a practical suggestion until ship design, navigation science, and logistical capability made its implementation possible.

[31] Robson, 10, adds that a primary purpose of the strategy was to isolate French colonies from support from home, which essentially made them the easy prey of roving British squadrons and expeditionary forces. Canada, the French Caribbean islands, and India all became targets of concentrated British assaults.

[32] Rodger, *Command*, 251.

was increasingly being dominated not by the nation with the best mariners, but the one with the societal structure amenable to the vast and complex tasks of ship building, victualling, ship maintenance, manning, officer training, navigation development, and one committed to providing long-term steady funding for these institutions.

And these institutions would become more important a decade later when the fragile peace established after the War of Austrian Succession, relatively independent colonial political entrepreneurs, and the loss of Minorca (due largely to the timidity of a British admiral executed for his caution), reignited the belligerence between France and Britain in the Seven Years' War.[33] For the British, this rush to war unfortunately followed a rare period of mass naval demobilization following the last peace and required an extremely rapid rebuilding made possible by Britain's extensive maritime community and the determination of William Pitt.[34] Once again, this was a global war; the navy was essential and maritime trade objectives were paramount. And again maritime interests displayed dismay at the fruits of victory when Commodore Moore took Guadeloupe in the Leeward Islands in 1759. The conquered rejoiced at their newfound access to British markets, while established sugar growers groused about new competition.[35] The English finished the work of the past few wars by re-taking Louisbourg and capturing Quebec and the rest of French Canada. The Western Squadron blockaded Brest and the French Atlantic ports. Hawke, again in command at sea, created an inshore squadron to

[33] Rodger, *Command*, 265-272, notes that the execution of Vice-Admiral John Byng on his own quarterdeck on 14 March 1757, despite the presence of his friends in control of the government, "reinforced the culture of aggressive determination which set British officers apart from their foreign contemporaries, and which in time, gave them a steady mounting psychological ascendancy."

Robson, 12-13, states the view of a not inconsiderable number of contemporary and historical observers that Admiral Byng was scapegoated. And that the entreaties for mercy by such influential friends as the Southern Secretary of State William Pitt (the Elder) did more harm than good, due to the animosity Pitt aroused in other officials and King George II.

[34] Robson, 15-17, observes the number of men in the Royal Navy dropped from 50,596 at the end of the War of Austrian Succession in 1748 to only 8,346 in 1753. Even Anson's request for a 3,000 man reserve was refused by the administration headed by the First Lord of the Treasury Henry Pelham. When war was imminent, Britain was able to enlist 20,175 men in the first six months of 1755 (one of whom was James Cook).

[35] Rodger, *Command*, 277.

monitor the harbors and communicate with the offshore fleet in relative safety. He expanded the durability of his fleet, both ships and men, by rotating ships to port and regularly provisioning his ships with fresh produce at sea.[36] The British ships suffered physically in the long blockade, but the British seamen, officers, and crews increased their proficiency. When the French did face him at the Battle of Quiberon Bay in late November of 1759, the result for them was disastrous.[37] British determination to fight, their preference for ship-killing hull targeting versus the French preference for targeting rigging to retard maneuver, and British seamanship told.[38] The French invasion plans for Scotland were effectively eliminated by Hawke. Although the sweeping British victory in the Seven Years' War was somewhat squandered at the peace negotiations which culminated in February of 1763, Britain had secured its position as the world's dominate sea power.[39] Although its fortunes would ebb and flow during the American Revolution and the early stages of the Wars of the French Revolution, by the time Nelson shattered the combined Franco-Spanish fleet at Trafalgar in 1805, its preeminence at sea would be unassailable for the next century. The institutional basis for this predominance and the national commitment to sustaining it was built up from the days of Elizabeth's 'Sea Dogs' to Hawke's year-round Atlantic blockade. The institutional growth of this marine culture also emerged in sync with other modernizing institutions of the British state. In fact its lead in

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[36] Dull, 82, notes that this massive administrative supply operation was made possible by Anson's return to the Admiralty as First Lord in 1757.

Rodger, *Command*, 281.

[37] The date for both Britain and France are the same for this battle as the British had finally adopted the Gregorian calendar in 1752 by eliminating the dates of September 3 to 13 and starting the New Year on January 1st, 1753.

[38] Dull, 75, notes the same French targeting preference at the Battle of Minorca in May of 1756.

Adkins, 104-105, notes that this preference survived well into the Napoleonic Wars and was demonstrable at Trafalgar. Some navies like the British focused their guns on the hulls – in order to disable ships and gun crews; other like the French and Spanish targeted the rigging. It was this knowledge that convinced Nelson that his ships could survive his mile long perpendicular assault on the Allied line at Trafalgar.

[39] Robson, 12, cites the treaty executed in Paris in February of 1763 which ended the naval war and observes the irony that even though France ceded Canada to Britain (Article IV), that it also preserved French fishing and shore rights in Newfoundland (Article V). Article VI added that Britain would cede the islands of St. Pierre and Micquelon [*Collectivité d'Outre-mer de Saint-Pierre-et-Miquelon*] to serve as shelter for these fishermen. These islands off the southern coast of Newfoundland are a self-governing French territory to this day.

developing large scale modern bureaucratic infrastructures, both public and private, predated British modernization in many fields and must have had a somewhat exemplary impact as the institution as a whole, with all its recognized faults, was revered by the public and both political parties. Even though eighteenth century Royal Navy institutions would not withstand hypersensitive modern inspection for probity, the efforts of its notable leaders from Pepys to Anson were remarkably public spirited and forthright for their day.

Anson, who served as First Lord during the Seven Years' War, ferreted out corrupt contractors involved in victualing, arming, and maintaining the fleet; he improved the medical care of seamen and veterans; and enhanced discipline and reduced the impact of favoritism by revising of the Articles of War for Parliamentary approval (one of the inspirations for the modern Uniform Code of Military Justice or UCMJ).[40] He greatly enhanced the professionalism and unity of the officer corps by standardizing uniforms for commissioned officers and working within the seniority system and 'beaching' or 'yellowing' (superannuating) ineffective senior captains and admirals which tradition prohibited him from dismissing or passing over for promotion.[41] He was responsible for transferring the control of the Royal Marines to direct naval control fulfilling another of Dr. Dee's recommendations put forth in *The Perfect Arte of Navigation* for a dedicated corps of "sea soldiers."[42] He also introduced a more logical system for rating ships by tonnage and the number of guns.[43] Although his discipline was in his view

[40] The original articles of war had Commonwealth inspiration, but dated to the beginning of the Restoration and Samuel Pepys – see footnote 9, Chapter 6. The 1749 Naval Act promulgated by Anson updated the articles and in Article II spelled out thirty-six categories of obligations and offenses, and the punishment for disobedience.

[41] Herman, 261 and 267, notes that one on Anson's protégés, Lieutenant Philip Saumarez created the design.

Robson, 9, notes that Anson "promoted capable admirals such as Boscawen, Hawke and Saunders to counter the existing group of elderly and incapable officers." He notes, 32, that at the beginning of the Seven Years' War it was not uncommon for junior admirals to be in their seventies, noting Rear Admiral Henry Harrison, who was almost seventy and commanded a squadron joined by Cook's *Eagle* early in the war.

[42] Dee, *The Perfect Arte of Navigation*, 5-6.

[43] Rodger, Command, 296, the army revived its marine regiments in 1739; Anson secured control in 1747.

necessarily harsh to maintain order among the large number of pressed landsmen aboard, he also improved the common sailor's meal rations and grog allowance.[44] What he achieved was the reformation of a service that would be able to man and sustain large effective globally dispersed battle squadrons year-round that regularly outfought their opponents at home and abroad.

What we are assessing is how British society provided the institutions, resources, manpower, intellectual capital, and physical infrastructure to support this enormous endeavor. We will further our exploration upon the impact this commitment had on the evolution of that society. And lastly, we will continue to ask if that understanding helps illuminate the modernizing and state formation process of sixteenth and seventeenth century England and eighteenth century Britain. In previous chapters we looked at the impact of exploration, science, mathematics, navigation, finance, ship design, intelligence, and trade upon the maritime project, therefore, we will focus the balance of this chapter on the Royal Navy's bureaucratic organizations and its contracted logistics network; its personnel; and its dockyards. We also briefly touch on its demand on natural resources and upon its colonies.

The Administrative Institutions of the Royal Navy

Although successive English kings to varying degrees had commissioned war ships or requisitioned merchantmen for military service, it was not until the Tudor period that we see the

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Herman, 267-269. Anson designated his first three rates, ships of at least two gun decks and 60 guns, as battleships, "fit to stand in the line." The fourth to sixth rates were designated as cruisers, used for scouting, convoy protection, and commerce raiding. The fourth rate was usually a two decker of 50 to 60 guns removed from the line of battle in 1756. Fifth and Sixth rates were frigates. Sloops and two masted brigs were unrated ships commanded not by post captains, but by commanders.

Rating ships had in fact existed since early Stuart times based on numerous factors gauging the number of crewman, guns, gun decks, and tonnage – either displaced or with regard to capacity. Rates were repeatedly redefined and adjusted by naval luminaries such as King Charles and Samuel Pepys. However Anson's rates survived the Age of Sail with some change and inspired French imitation.

[44] Of the 36 Articles of War in Anson's Navigation Act of 1749, twenty provided for punishments including death. Article 1 carried on the Protestant nature of the service by requiring regular worship. Twelve more articles described court martial offenses, the 35th Article applied the entire code to conduct ashore while in service, and the 36th Article provided a 'catch all' for maintaining order by prescribing for offenses "which are not mentioned in this Act," such punishment "according to the Laws and Customs in such Cases used at Sea."

creation of permanent institutions established to sustain the Realm's naval ambitions (see Chapter 5, Early Tudor Research Programs and Institution Building). The two primary institutions responsible for the execution of these ambitions were the Admiralty and the Navy Board (both had various guises over the convulsive changes from kingdom, to republic, to military dictatorship, back to kingdom, and eventually to a constitutional monarchy). Without rehashing the intricate history of these institutions' sixteenth and seventeenth century evolutions, we will touch briefly upon their history before examining the eighteenth century institutions that did so much to sustain and create British global sea power.

Even though the office of Admiral of England (Lord Admiral; later Lord High Admiral) had existed since 1385 and was one of the nine Great Offices of medieval England, the position was often ceremonial and was not supported by an established bureaucracy of professional civil servants or maritime advisers until well into the seventeenth century.[45] In theory and at times in practice, the Lord High Admiral exercised operational control of the crown's fleet and its drafted merchantmen in times of crisis. However, the ceremonial nature of the post was often evident as Rodger notes that the Lord Admiral was in fact a child from 1525 (the king's illegitimate son the Duke of Richmond), and that Cardinal Wolsey used the vacancy to direct the navy through its Keeper of the Storehouses, William Gonson.[46] Some Lord Admirals such as Charles Howard did have considerable maritime experience, but even though he led Elizabeth's attack on the Spanish Armada, he also ascended in part due to familial ties. He was a descendant of William Howard who held the post from 1554 to 1558 and his chief compensation was derived from running the

[45] The Lord High Admirals from 1385 to 1628 most often were courtiers and included the bastard children of the crown still in their minority. Very few sea officers held this position and most were noblemen awarded the position for either personal or familial service to the king.

[46] Rodger, *Safeguard*, 223.

Herman, 35-36, 42, notes that early in Henry VIII's reign, before his reforms, the Lord Admiral was a judicial post and that this office holder was a boy of seven.

courts that adjudicated customs and piracy disputes. However, the junior of these two organizations, the Navy Board, can trace the creation of its proto-modern bureaucratic character to the Tudors.

In order to support their fledgling navy, the Tudors turned to mariners and men of lower station. Henry VIII appointed by letters patent the Navy Board from the *King's Majesty's Council of His Marine* on 24 April 1546. This board was responsible for the administrative functions of the navy. It was tasked with getting the navy to sea, where it would be commanded by the Lord Admiral or one of his lieutenants. The Navy Board reached the pinnacle of its early effectiveness during the Tudor period under the able direction of Elizabeth's erstwhile slaver and pirate John Hawkins (from 1577 to 1595). He presided over the board in his position as Treasurer of Navy, was responsible for its financial affairs, and was subordinate to the Lord Treasurer. As we noted earlier, much of the credit for the fighting effectiveness of Elizabeth's race galleons are attributed to his personal direction of the maintenance and new construction of the ships of the fleet. The other Board members included the Controller who procured timber and stores, the Storekeeper, responsible for storing supplies, the Surveyor, in charge of ship building and repairs, and the Clerk of Ships who acted as the Board Secretary. An additional member, the Master of Naval Ordnance, attended and reported to the Ordnance Board.[47] However, even though this Board, its directors and their clerks and associated contractors in the Royal dockyards did work on behalf of the crown, they were "not salaried civil servants, so much as privileged contractors with an ill-regulated business with the crown."[48] Hawkins

[47] Rodger, *Safeguard*, 331, notes that this position was filled by William Winter in 1557.
[48] Ibid, 332-334, observes that the respective commissioners of Tudor Boards negotiated a fee for service relationship with the Crown that was predicated on ships afloat, or seamen both ashore and afloat. The negotiated fees often did not adjust with price surges or shortages sparked by large-scale mobilizations and the contractors often either lost heavily or provided poor quality stores. In addition, government was often in arears and these contractors became heavily indebted or bankrupt.

maintained the navy for a fee, but he was notably honest and efficient by the standards of the time, and he did not enrich himself. However, in an era when the chief perquisite of a royal position was the wealth to be garnered through its transactions and where pay was minimal and often grossly in arears, cupidity was common. Elizabeth's Lord Burghley attempted to limit its excesses by maintaining a balance of competing contractor factions, who often accused each other of gross malfeasance in order to secure contracts. Upon Burghley's demise in 1598, this system was replaced by his successors with the more contemporary practice of installing favorites regardless of merit. Rodgers adds that "after Hawkins's death the condition of the queen's ships seems to have noticeably deteriorated."[49] However, it must be noted, that although not a modern civil service, the Tudor Navy Board, consistently put well founded and provisioned ships to sea in sufficient numbers to thwart the greatest military and financial power of the day. This Board also established the administrative network capable of regularly assembling fleets and built up considerable expertise in ship design, ship maintenance, manning, and victualing. The corporate knowledge accrued and passed down by this board to its successors was modern in this sense. The increasingly expensive and logistically demanding naval warfare of the early modern period was stressing the capabilities of medieval institutions. The naval exertions of the seventeenth century required the support of a vast technical and logistical infrastructure and myriad specialists in its detail. Improvising merchant fleets for invasion or defense and entrusting their provisioning and assembly to trusted, but amateur lieutenants of noble birth was rapidly becoming unfeasible. The Tudor monarchs assembled technical private contractors under the aegis of commissioned crown agents to sustain its fleets, but the stresses of maritime innovation and increasing international competition driven by the new wealth created from maritime trade was making even this novel system untenable in the seventeenth century.

[49] Rodger, *Safeguard*, 338-339.

The early naval neglect of James I and his belated reforms of 1618, and the subsequent stress of his Spanish war left his successor with a naval administration incapable of facing the operational demands and financial stress put upon it.[50] Charles I, as we have noted previously (see Chapter 8), was involved in building up his Navy and aggressively addressed its chronic funding problems with innovative financing schemes (i.e. ship money). In 1628 he put the office of Lord High Admiral into commission which effectively ceded operational control of the fleet to a committee in the form of the Board of the Admiralty.[51] He in effect induced the creation of an operational bureaucracy similar in structure to the administrative Naval Board. However, the strains of consistently fielding an early modern navy were beyond the financial and administrative structures provided by the Tudors and the first two Stuart kings. As Rodger notes, "by the peace of 1630 naval administration had passed through three distinct phases since Queen Elizabeth's death: fifteen years of neglect and decay, six years of retrenchment and reform, and a further six of desperate wartime improvisation and deepening crisis."[52] This crisis of finance and administrative inadequacy although not solved by Parliament's or the Lord Protector's committees during the Interregnum, did in fact further develop the growing Admiralty and Naval Board's bureaucracies and capabilities, but troubles persisted throughout the Restoration period.

Charles II reinstated the office of Lord Admiral and the Navy Board superseded by Parliament. The reconstituted Navy Board, due in large part to the extraordinary talent of Samuel Pepys, was able to refit the fleet and under the command of the reinstated Lord Admiral of England, James Duke of York, muster one hundred ships which defeated the Dutch at the

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[50] Rodger, *Safeguard*, 370-371, notes that the Navy Board was replaced under James I with a commission whose 1618 reforms initially worked, especially in the reform and expansion of the dockyards that prolonged the life of the fleet and reduced necessary ship building expenses, but were in the end undermined by the new Spanish war (1627). By 1628, the Navy Board was back.

[51] When any of the Nine Great offices of state were without an officer holder the monarch could "put them into commission" or replace them with a committee or board to execute the functions of the office. The Board of Admiralty and its members were led by the First Lord of the Admiralty, who in time would also sit in the cabinet.

[52] Rodger, *Safeguard*, 372.

battle of Lowestoft in June of 1665.[53] But the Admiralty's and the Navy Board's financial difficulties were still not resolved and the disappointing end to the Anglo-Dutch Wars and the subsequent political troubles of James II were in part a result of numerable naval crises including the London march of unpaid sailors and the Dutch assault on the Medway.

Once again, the soldier-king William III provided the Navy with its needed reformation. He appointed an Admiralty Board to replace the position of Lord High Admiral.[54] This state existed with only a few minor exceptions from 1709 until 1964. After the reforms of the Restoration and of William III, the institutional structure of eighteenth century Royal Navy was relatively well established. The Navy Board managed the construction, manning (for both sailors and technical warrant officers), provisioning (less victuals), and maintenance of the fleet.[55] It audited the accounts of two other boards; the Boards of Victualling and of Sick and Hurt. With its myriad dockyards, warehouses, and contractors, the eighteenth century Navy Board "presided over the largest industrial organization in the world."[56] The Admiralty commanded the fleet at sea and advised the King on its operational direction.[57] Like the Navy

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[53] Rodger, *Command*, 109, notes that Charles II was eventually able to dissolve the Admiralty Board in 1684 and name Pepys as Secretary of the Marine, analogous to Colbert's position in France. However, this arrangement would not survive the Glorious Revolution and Pepys career would end with it.

[54] Dull, 26, this Board consisted of five MPs and two admirals with Admiral Herbert at its head.

The Board of Admiralty consisted of a number of Lords Commissioners of the Admiralty. The Lords Commissioners were always a mixture of admirals, known as Naval Lords or Sea Lords and Civil Lords, normally politicians. The quorum of the Board was two commissioners and a secretary. The president of the Board was known as the First Lord of the Admiralty, who was a member of the Cabinet.

Rodgers, *Command*, 186, notes another significant shift. By 1713, Queen Anne completed the work of the previous century by shifting responsibility for the navy from monarchal to parliamentary control. She retained responsibility for foreign policy and the army, but we can glimpse here the modern democratic form of military control.

[55] Dull, 16.

Robson, 40-41, observes that examining and certifying Royal Navy ship's masters was still the responsibility of Trinity House throughout the eighteenth century. The examination was conducted by merchant captains with no representatives from the Royal Navy included on the examining board.

[56] Herman. 240-241, adds that the Board's five clerks in 1694 had grown to sixty-three within a decade.

[57] Ibid, 188.

Dull, 15, notes that more specifically, it "made regulations, appointed officers, supervised the other boards, and shared with the cabinet, particularly the secretaries of state, the control of naval operations." Throughout our period (until 1782), the King was advised by two secretaries of state. The Northern Secretary was responsible for

Board it started to develop an institutional memory.[58] It appointed its commissioned officers, enacted its regulations, and supervised the other boards. All of these boards were increasingly staffed with permanent civil servants of long service.

As the scope of the Royal Navy's responsibilities increased, the Admiralty narrowed the Navy Board's portfolio to two critical areas: first, the maintenance and building of warships, and second, finance. From the middle of the seventeenth century we see an expansion in the bureaucracy to accommodate the growing size and complexity of its responsibilities. The Victualling Board was created in 1683, the Sick and Hurt Board was permanently commissioned from transitory status in 1715, and the Transport Board was created in 1690.[59] Anson was able to bring the Navy Board under tighter Admiralty control during his tenure and even though the subsidiary boards gained independence from Navy Board oversight, all of them, including the Navy Board were subsumed in the Admiralty bureaucracy early in the nineteenth century.

Hydrography and Captain Cook

Although the Admiralty did not formally establish a Hydrographic Office until 1795, the relatively new science of hydrography – physically describing coasts and oceans mathematically

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northern and eastern Protestant Europe and the Southern Secretary for southern and western Catholic Europe. The Southern Secretary was the senior of the two and in practice also was responsible for the Atlantic colonies. These divisions of responsibility proved to be more theoretical than practical, but the preeminence described was not.

Rodger, *Command*, 294-295, observes that a succession of First Lords of sound professional expertise (Admiral Edward Russell, now the Earl of Orford, (1714-1717), the Earl of Berkeley (1717-1727), Lord Torrington (1727-1733), and Sir Charles Wager (1733-1742)) greatly enhanced the professionalism of the Admiralty and distinguished the Admiralty from other political appointments solely based upon political patronage. He notes that "major naval operations were still officially the province of the Secretary of State;" and that "the Admiralty was the center of the naval system rather than its head.

[58] Rodger, *Command*, 296.

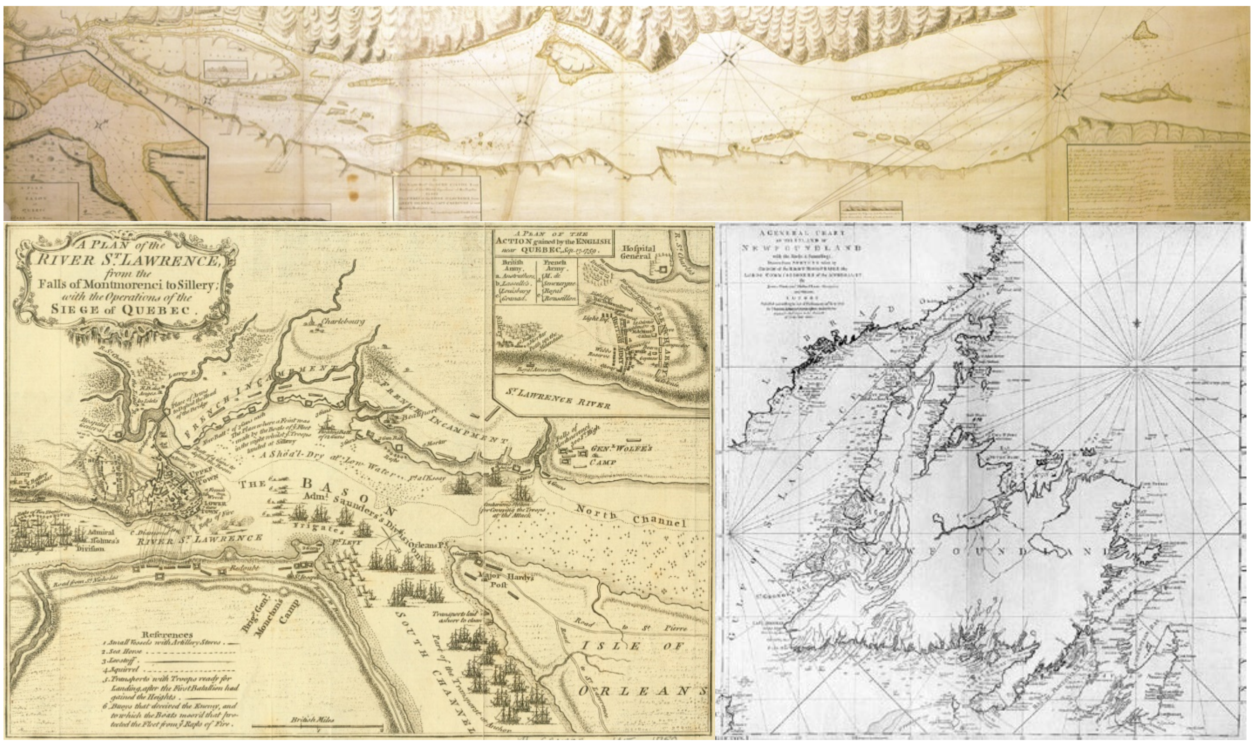
[59] The Sick and Hurt board was initially assembled in war time, as when the diarist John Evelyn was appointed by his friend Samuel Pepys during the Anglo-Dutch Wars (Rodger, *Command*, 104). It was first established in 1653 and was charged not just with treating English wounded and providing the fleet medical services and surgeons, but also with managing prisoners of war. It was made permanent in 1715 and subsequently absorbed into the Transport Board in 1806. This Board was in commission from 1690 to 1724 and re-established in 1794. It provided transport services for military personnel, supplies, and equipment. The Transport Board in turn was absorbed into the Victualling Board in 1817.

and pictorially; initially a blend of surveying, astronomy, cartography, and geography – expanded greatly in the eighteenth century, and especially during the Seven Years' War.[60] As we have noted earlier, the Royal Navy encouraged global operational charting which provided its forces with qualitative advantages over its adversaries and enhanced the survivability of its ships in distant waters. Narborough's seventeenth chart of the Straights of Magellan dedicated to Samuel Pepys (see Chapter 8) is an outstanding example of the product produced by the scientifically inclined officers that would come to dominate the ranks of the Royal Navy in the late eighteenth and nineteenth centuries. Rodgers has noted the decisive impact in amphibious operations from the Americas to India which this mathematical cataloguing and graphical representation of the earth's shorelines and oceans had upon its overall success in its colonial wars.[61] But this technical competence was not originally the province of officers.

As we have observed, the combination of technical skill and social rank within the same individual was not the norm in Europe prior to the modern era. Technical capability generally resided in craftsman and contemporary leaders left those tasks to their social inferiors. John Robson in his *Captain Cook's War & Peace: The Royal Navy Years 1755-1768* reminds us that well into the eighteenth century chart making and hydrographic surveys were the responsibility of the ship's senior warrant officer, the master; it was not the responsibility of the lieutenants or the captain.[62] Officers like Narborough were an exception, but as Britain's global role expanded and as its association with the Royal Society became more durable, we observe as with so much else in the eighteenth century Royal Navy the emergence of an officer corps with a wide array of

[60] Robson, 62, also notes that RN officers had been advocating for its creation since at least 1740. The author also notes, 67, the proliferation of published texts on both surveying and navigation printed in the 1740s and 1750s.
[61] See footnote 82, Chapter 8.
[62] Robson, 62 and Appendix II, notes the 'Masters' Regulations and Instructions' circa 1750 address these responsibilities in Article VII, whereby "He is to apply himself to observe the appearances of coasts and how they show themselves in different points of view and if he discovers any new shoals or rocks underwater, to note them down in his journal, with bearings and depth of water."

technical competencies. Although Captain Cook was remarkable for his chart making diligence, to single out just one of his exemplary attributes, he soon became an archetype of what the modern naval officer should be capable of in war and peace. And once again the midshipman apprenticeship program of King Charles II and Pepys contributed to this trend. As most senior midshipmen would serve as master's mates before passing for lieutenant, they would get an early exposure to charting and hydrography while assisting the master.



Map 9.1. Early Charts of Master James Cook. The surveys of the Saint Lawrence River made by Cook and three other ship's masters in the winter of 1759 led to the spectacular success of Major General James Wolfe's capture of Quebec which effectively ended the French presence in North America. His chart of the channels (top – left side, south of *Ile d'Orléans*) through 'The Traverse' provided Admiral Saunders with a navigable route to the city while avoiding most French resistance.[63] Wolfe's and Saunders dispositions around the besieged city are presented (left) and appeared in the *London Magazine* that year.[64] Finally, Cook's extensive survey of Newfound (right) following the Seven Years' War (but published in 1775), demonstrates the minute detail that characterized

[63]Jefferys, Thomas, "James Cook's Chart of the St Lawrence to Québec by Order of Vice Admiral Charles Saunders 1759," May 26th, 2008, Sailingwarship.com, http://www.sailingwarship.com/james-cooks-chart-of-the-st-lawrence-to-quebec-by-order-of-vice-admiral-charles-saunders-1759.html.

[64] "A Plan of the River St. Lawrence, from the Falls of Montmorenci to Sillery; at the Operations of the Siege of Quebec," Copperplate map, 17.5 × 24.4 cm, From *London Magazine*, November 1759.

Robson, 82, observes that "The French had naively assumed that the British would not be able to pass the Traverse and had, therefore, not set up any defensive positions.

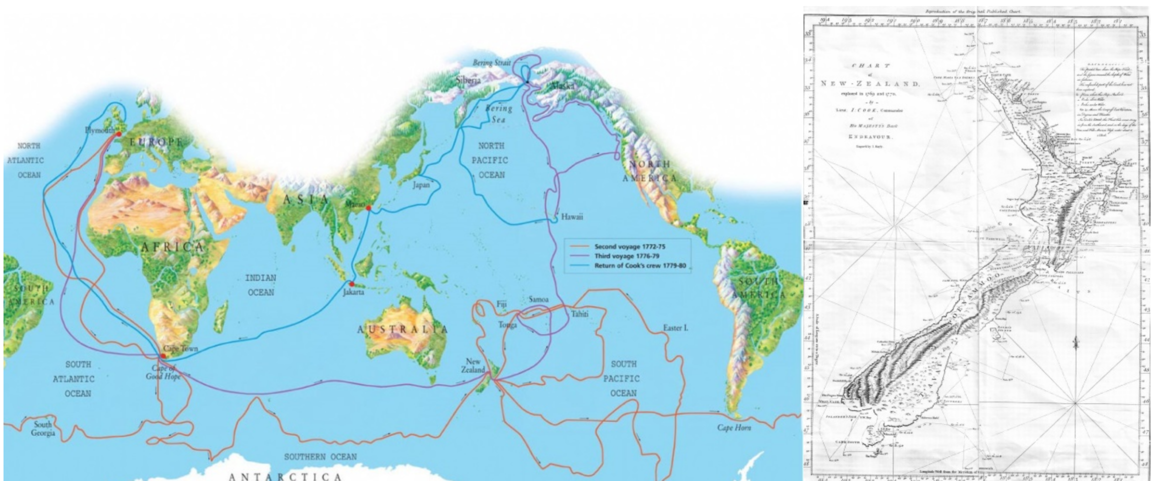
Cook's extremely accurate surveys.[65] The survey was completed by Cook's first mate Michael Lane, whom he had trained in his last yearly expedition. Developed with the aid of local pilots, this chart was so accurate that it was used for 100 years.[66]

Cook developed his hydrographic skills under the surveying tutelage of an army engineer of Dutch descent, Samuel Holland. His services had been instrumental to Wolfe during the latter's successful assault on Louisbourg the year before and at the siege of Quebec.[67] Mostly self-educated and of low social origin, Cook nevertheless became the premier hydrographer of the eighteenth century. His first major project after the Seven Years' War was the mapping of Newfoundland (see above). Working with local pilots to identify rocks and shoals, Cook employed land survey techniques (triangulation) to create charts that would eliminate the need for localized expertise in the future.[68] He was an exemplar in the early modern project of codifying local knowledge and physical detail, and in making it widely accessible. The quality of his work in French Canada and mapping Newfoundland brought him to the attention of the Admiralty and the Royal Society. In 1766, he was promoted to lieutenant and given command of their joint Pacific expedition to observe the transit of Venus and assess its efficacy in longitude determination and later to search for the great southern continent (*Terra Australis*).[69] The quality of his charts and observations earned him promotion to commander and a second Royal Society expedition. This expedition and its descent to 71 degrees south latitude finally dispelled

[65] By Michael Lane and James Cook - originally uploaded to en.wikipedia by Jcmurphy on 23 Apr 2005; copied from "Courtesy of the Centre for Newfoundland Studies, Memorial University of Newfoundland, St. John's, Newfoundland," also "Les cartes de Terre-Neuve et du Labrador de James Cook," Heritage.nf.ca, http://www.heritage.nf.ca/articles/en-francais/exploration/les-cartes-de-james-cook.php.
[66] Robson, 125.
[67] Ibid, 47. The author notes that Cook was encouraged to indulge his interest with the earnest support and library of the captain of HMS *Pembroke*, John Simcoe.
[68] Ibid, 160.
[69] This continent was postulated as a balance to the northern continents, but after nothing was found south of New Holland and New South Wales, that smaller continent was given the name Australia since nothing habitable lay south of it. For contemporary conjecture even into the eighteenth century see Abraham Ortelius' 1570 map of the world, *Typus Orbis Terrarum*, depicting "Terra Australis Nondum Cognita" – Chapter 6.

Robson, 183, observes that Alexander Dalrymple, who was appointed by King George III to be the first Royal Hydrographer in charge of the Admiralty's Hydrographic Office in 1795, was originally intended to lead the mission. However, he resigned when Admiral Hawke refused to give command of a Royal Navy ship to a civilian.

the southern continent myth and confirmed the efficacy of Harrison’s chronometer in longitude determination (see Chapter 8). He was again promoted upon his return (to post captain) and made a fellow of the Royal Society. On his third and final Pacific journey, Cook set out to find that most elusive of navigational prizes, the Pacific egress of the Northwest Passage. He discovered the Hawaiian Islands, delivered the Passage its death knell, and unfortunately upon returning to Hawaii, the natives delivered him his.[70]



Map 9.2. The Three Pacific Explorations of Captain Cook.[71] Cook’s groundbreaking scientific expeditions to the Pacific introduced Europeans to the East Coast of Australia (Botany Bay, New South Wales) and Hawaii (the Sandwich Islands) for the first time. He produced the first detailed charts of Australia and New Zealand (right) and put to rest any hope of a navigable Northwest Passage or another southern continent. Cook’s first voyage (1768-71) on HM Bark *Endeavour* reached Tahiti in eight months with no incidents of scurvy. The expedition astronomer Charles Green observed the transit of Venus.[72] On his second Voyage (1772-75) aboard *Resolution*, Cook tested Harrison’s navigation chronometers and discovered multiple southern islands. On Cook’s last voyage (1776-1780), again on *Resolution*, he focused on the Pacific Northwest and found the Hawaiian Islands. After a return visit Cook was killed by the islanders on 14 February 1779.

[70] It is also not unreasonable to argue that the 1791-1795 expedition of Captain George Vancouver to the Pacific Northwest dealt the final blow to passage proponents (see Conclusion, footnote 10) and that Cook’s was the penultimate blow.

[71] Annotated map image from https://www.q-files.com/images/pages/galleries/1026/captain-james-cook-12.jpg and New Zealand chart image from https://commons.wikimedia.org/wiki/File:Cook_chart_of_New_Zealand.jpg.

[72] Robson, 184, observes that these measurements when compared to those taken elsewhere on the planet where used to calculate the distance of the Earth from the Sun by using the principal of parallax prescribed by Edmund Halley in 1716. Jérôme Lalande, a French astronomer, used data from two sets of observations from 1761 and 1769 to calculate a distance of 153 million kilometers (modern calculation of 149.6 million kilometers).

Victualling

Large armies on the continent had the advantage of being able to live off the land, much to the dismay of the people who were unfortunate enough to live on that land. Navies did not have that option. They needed to bring their foodstuffs with them. Provisioning or victualing ships for long periods at sea proved to be one of the most complex problems facing the late medieval governments in Iberia or the North Atlantic. Simply put, the sailing and navigation technology of the day was far superior to the institutional capabilities of late medieval society. Ships that could circumnavigate the globe and survive the gales of the North Atlantic were of little use if the crews which sailed them died of disease and starvation, or if they could not affect repairs due to a want of sailcloth, timber, yards, or cordage. Sailing fleets required large quantities of specific naval stores and wholesome food and water preserved for extreme temperature and moisture variations. Sixteenth and seventeenth century food preservation technology was limited to drying and salting; operations that were seasonal.[73] For all extensive purposes this technology would not be improved until the advent of canning in the early nineteenth century; an advance that was driven by French military requirements on the continent and British naval requirements at sea.[74] The English adjusted to these demands by emphasizing an almost religious cleanliness aboard ship and by attempting to provide an abundance of beef and beer.[75] They relied on private contractors, often of dubious integrity, to provide their

[73] Rodger, Command, 41, notes that "the technology of the age permitted beer to be brewed and meat packed only in the winter months." This limitation necessitated prior planning and funding for all spring and summer operations.
[74] The Napoleonic French government offered a prize of 12,000 francs for the invention of an improved and cost effective method of preserving food to sustain its armies in winter time when their usual foraging tactics were impractical. In 1809 Nicolas Appert recommended cooking and sealing food in glass jars and was awarded the prize a year later. Once again we see technological advancement divorced from theory as Louis Pasteur's experiments highlighting the role of microbes in food spoilage were a half century away. French and British entrepreneurs patented a canning process in London and it was bought by Bryan Donkin and John Hall. They used sealed cans of tinned wrought iron. The high cost of the process made the military the first reliable customer. The Royal Navy bought canned beef and canned food made its way to the artic with the Navy's explorers Parry, Ross, and Franklin.
[75] Robson, 27, notes that each sailor in home waters was guaranteed eight pints or a gallon of beer a day.

supplies, and it was only through the acquired technical knowledge and improvised audit procedures of civil servants like Pepys that the negative impacts of corruption, if not eliminated, were at least mitigated.[76]

Rodger notes that throughout the eighteenth century, "British naval victualling is a remarkable story of rising standards, making ever more extended operations possible," and that "higher standards came at steadily falling expense."[77] As we have addressed earlier and will expand on below, the dramatic English (and now British) advantage in dry-dock technology gave The Royal Navy's ships longer lives and more staying power on station. When this advantage was combined with Britain's advantages in victualling, heretofore impractical naval strategies like all-weather blockades and the Western Squadron became reality. History celebrates the genius of men like Hawke and Nelson, but the Navy Board's steady accumulation of institutional proficiency in providing biscuit and dockyards was of paramount importance in Britain's dominance of the seas. They excelled vis-à-vis their contemporaries by tapping the strength of the English maritime community and working within the confines of that culture in a public-private partnership that had no rival. Napoleon's maxim that amateurs discussed tactics while professionals concerned themselves with logistics was evident at sea a half-century before the malignant brilliance of his staffs were felt across Europe.

Once again, the demands of the maritime community had deep impacts upon British society and its fitful evolution towards modernity. The Victualling Board, as the largest single agricultural consumer in Britain, shaped that market to favor large competing concerns, and was

[76] Rodger, *Command*, 105, notes Pepys' significant contribution to reforming the purser's allowance in 1644 by eliminating the per man *per diem* and substituting it with a ship allowance. This pitted captains and pursers against each other, but eliminated their incentive to assist in each other's respective peculation.

[77] Ibid, 306, observes that the Navy Board spent approximately the same amount to victual 70-85,000 men during the Seven Years' War as it had on victuals of inadequate quality for its 40-50,000 sailors during the War of Spanish Succession half a century earlier. He cites the yearly costs of £913,905 in 1758 and £942,879 in 1710 for the aforementioned numbers of seamen.

a significant player in the evolution of agribusiness in Britain.[78] The activities of the maritime bureaucrats within the Navy Board were not just providing the naval implements to eighteenth century British policy makers. They were, whether inadvertently or not, shaping labor policy at the dockyards, agricultural policy in the London commodities markets, and business development at home and abroad. As the needs of the Royal Navy grew, so did the expansion of the middle class industries needed to support its mission.

The Sick and Hurt Board

Although this institution served navy interests, its origins can be traced in part back to the medieval mariner's guilds like Trinity House. John Hawkins borrowed their structure when he established Chatham Chest in 1590 on a payroll deduction model to fund support for wounded seamen in a system that foreshadowed elements of workers compensation insurance and social security withholding.[79] In addition to assembling finances for the lame, the Royal Navy was an early pioneer in providing dedicated facilities for its wounded, although its first hospitals were designed with multiple goals in addition to rehabilitating the sick. Keeping sailors from deserting and maintaining discipline during convalescence were equally important.[80] Over time these hospitals replaced the ad hoc arrangements the Tudor administrators made with private boarding houses. After Admiral Russell defeated Tourville at Cherbourg and La Hougue in 1692, Queen Mary in gratitude ordered the construction of the Seaman's Hospital at Greenwich; ironically, her father James's project.[81] Although England's first permanent service hospital, it

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[78] Rodger, *Command*, 307.

[79] Rogers, P.G., 37, "It was a fund, built up by compulsory contributions deducted from seaman's pay, for the relief of the sick and wounded."

Rodger, *Command*, 104-105, notes the rates allocated for specific injuries. This is similar to our modern workers compensation allowances for specific losses of limbs or eyes.

[80] Rodger, *Command*, 309, notes the massive seaman's hospital at Haslar outside Portsmouth, its huge expense, and its vast size. It was also designed to not just segregate infectious diseases, but to impede attempts at desertion.

[81] Herman, 226.

was preceded by Louis XIV's *Les Invalides* which he constructed in Paris from 1670 to 1676 for the wounded veterans of his many wars.[82] Samuel Pepys had established a school for navigation at the site in 1685, and as we have noted, Greenwich would also serve as the home of the national observatory and the prime meridian. Located east of London on the southern bank of the Thames next to the Deptford Royal Dockyards, Greenwich and its hospital was at the heart of the British naval world.

Although financial resources and infrastructure were dedicated to wounded seamen in the seventeenth century, it was not until the eighteenth century that Britain established a permanent institution to manage the care of wounded sailors and prisoners of war that had heretofore been addressed by wartime committees or boards which were disbanded at the end of hostilities. The specific organization and charge of the Sick and Hurt Board came from the Commonwealth in the 1650s.[83] Although it and its successors were disbanded, the responsibilities of the eighteenth century successor board expanded and eventually it became responsible for assuring the health of sailors at sea, addressing virulent seaborne illnesses, and providing warrants for ship's surgeons and their mates. Over time, it replaced the College of Physicians as the Admiralty's resource for medical recommendations concerning these debilitating diseases.

Even though much has been written about the deadly effects of scurvy, its eventual control with citrus fruits or Vernon's preventive method of mixing water, rum, and lime juice to create the daily palliative and anti-scorbutic seamen's grog, this early killer on long voyages was

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Rodger, *Command*, 195, the hospital was intended for disabled veterans along the lines of *Les Invalides*. Russel also appointed the first naval physicians at the home ports of Rochester, Deal, Portsmouth, and Plymouth. By 1711, the first overseas hospital was built at Port Mahón.

[82] The *Hôtel national des Invalides* (The National Residence of the Invalids)

[83] Rodger, *Command*, 47-48, notes that the Commonwealth Sick and Hurt Board was established to handle the wounded ashore and provide pensions for the maimed or widowed. He adds that "it established a precedent which was to be drawn on for over a century."

effectively under control in the Royal Navy by the end of the Seven Years' War.[84] Anson's and Hawke's provisioning of fresh produce at sea had remarkable effects and as Rodgers notes, "the anti-scorbutic value of fresh meat and vegetables, derided by medical science then and for long afterwards, was well known among seamen."[85] Once again, technical progress outstripped theory. However, it would be a naval surgeon who would confirm the remedy with what Herman cites as "the first controlled experiments in medical history."[86] Adkins notes that this control of scurvy was a decidedly British achievement. Even as late as 1805 the disparity between British and French hygiene efforts were evident during Nelson's long pursuit of the French leading up to Trafalgar. "After chasing Villeneuve and his fleet from the Mediterranean to the West Indies, Nelson was able to boast that he had not lost a single officer or man through sickness on the entire trip."[87] The French had to beach one thousand men who were unavailable for the subsequent and determinative battle. Unfortunately the more deadly killer on cramped wooden warships did not have such a manageable remedy.

Fevers like typhus ('goal fever'), malaria, and other tropical diseases were much harder to combat, and often decimated the crews of individual ships, entire fleets, or large numbers of men ashore crowded in ports or assembled for amphibious operations. The Navy's only remedy, tailored more for lice-borne diseases like typhus, was enforcing a puritanical cleanliness for the

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[84] Vice-Admiral Edward Vernon's alcoholic mixture, issued to his seamen in the West Indies during the War of Jenkin's Ear (August 1740) derived its name from his nickname 'Old Grogram' or 'Old Grog' inspired from the coat he wore of grogram cloth.

Robson, 17, notes Cook's early experience with scurvy and typhus during the Seven Years' War and his future dedication to ameliorating its effects on his subsequent long Pacific voyages.

[85] Rodger, *Command*, 305 and 308.

Rodger, *Safeguard*, 318, notes Sir John Hawkins' recommendation in the late sixteenth century to combat scurvy by eating oranges and lemons.

Rodger, *Command*, 133, provides the example of the explorer John Narborough in the 1670s curing his crew "of scurvy with herbs and fresh meat," during his cartographic expedition to the Strait of Magellan.

[86] Herman, 260, notes that the surgeon of HMS *Salisbury*, James Lind, published his findings in 1757 and dedicated them to George Anson, the First Lord who had suffered personally from scurvy on his circumnavigation.

[87] Adkins, 32-35.

ship and the crew alike.[88] This dedication to hygiene was unique for its day at sea, and in most cases ashore, but was remarkably effective. Dull, by contrast notes that "French ships were more prone to epidemics such as typhus, probably because standards of cleanliness on most of its ships were much inferior to British."[89] Since water purification technologies were for all extensive purposes unavailable on wooden ships, water-borne diseases were fought with alcohol. Although moderns remark when informed at the quantity of the seamen's daily allowance, its use was also hygienic and was intended to be preventative. The significant observation to note is that the Royal Navy was an institution that promulgated corporate solutions to serious problems of health and welfare. Despite its conservation reputation with regards to tradition and technology, the navy often innovated. Successful practices themselves became tradition few captains would dare to assault and the institution as a whole gained useful wisdom which survived its current leadership. The Royal Navy also benefited from the accumulated learning and technical expertise of English institutions of long pedigree which supported the Navy, but which were not subordinate to either the Admiralty or the Navy Board.

Ordnance Board

The Board of Ordnance was another Tudor institution that played a large role in the development of English society and its presence on the world stage while supporting the realm's maritime ambitions. As we noted in Chapter 5, this independent board, headquartered in the Tower of London was pivotal in the development of England's iron foundry industry.[90] In

[88] Rodger, *Command*, 308.
[89] Dull, 18.
[90] The responsibility for cannon and fortifications predates the Tudors and as early as the 1320s the monarchy was involved. The operation was headquartered in the White Tower of the Tower of London, the Norman fortress on the Thames built by William the Conqueror in the 1080s. Henry VIII formalized and structured the Office of Ordnance operation at the Tower in 1544 as he did so much else during his reign and by 1597 it was the Ordnance Board. In 1683 Lord Dartmouth issued a new constitution for the Board of Ordnance, formalizing its mission and the duties of its officers which largely survived intact until its disbanding in 1855 after its performance during the Crimean War.

addition to supplying the Army and Navy with munitions and artillery, it also operated the coastal forts and castles of the realm. Like many of the bureaucracies in eighteenth century Britain it expanded its reach and founded the Artillery and Engineer Corps. It also ran the Crown monopoly on the production of gunpowder.

During the Tudor period Rodgers notes that although it would be considered "corrupt and slothful by modern standards," it was demonstrably more able than the comparable offices in Spain.[91] It operated a staff of 150, built up a large stockpile of powder, shot, skilled gun-founders (both public and private) and a strategic reserve of bronze. Like the Navy Board, it directed a competitive network of private contractors and directed a global market not just in iron, but in commodities which required Britain's new global maritime routes. Although it manufactured gun powder at home with its private contractors, it assembled the best raw materials from far afield. The Ordnance Board imported saltpeter from Bengal and the best sulfur from Sicily and Iceland.[92] And like the Navy Board, the Ordnance Board entered its operational maturity during the Seven Years' War. What we see again is the demand placed on medieval institutions by global aspirations and the subsequent development within these evolving bureaucracies to address the demand which simultaneously fostered the development of middle class business networks. As their prowess grew, so did the extent and distance of their networks. The demand for quality gunpowder for the fleet opened long-distance trade routes that required increased naval acumen and power for its security. This demand also fostered the development of a productive class that would themselves use Parliament to condition policy for their benefit and foster their growth. To command the sea, a nation needed to use the sea to tap the resources of the globe. The capture of the national spirit by the maritime class begun under

[91] Rodgers, *Safeguard*, 340.
[92] Rodgers, *Command*, 309-310. The Board also encouraged the adoption of the novel Swiss technique for casting solid iron cannon and boring their muzzles.

Elizabeth was complete by the eighteenth century. Britain, as her citizens now envisioned her could not exist without the sea, global commerce, or competitive nascent capitalism. British society and its multifaceted maritime subcultures were inexorably intertwined. The Tudor courtiers and their subsequent private contractors had now been replaced by a growing class of naval civil servants and merchants who were shaping the British economy and therefore its society based upon the imperatives of global maritime trade and naval exigencies. This maritime-public convergence was also creating an entirely new class of technically competent and socially prominent leaders.

***Butescarli* to Professional Sea Officers**

The amalgam Saxon-Danish tradition of an on-call national fleet mustered very like the Saxon *fyrd* but for sea service, the *scipfyrd*, had for all extensive purposes been eliminated by the Norman Conquest.[93] However, Rodger suggests that one vestige of that system, a small permanent Saxon sea patrol in the eastern end of the English Channel (the Narrow Seas), whereby year-round local sea service was exchanged for special privileges for the port cities providing these ships and sailors, survived in the Kentish Cinque ports. The men of these ports were referred to as *butsecarls*.[94] This Saxon word draws land parallels to the household troops or *huscarls* of the Norse and Saxon kings and lords.[95] The idea of national military sea service

[93] Saxon military organization comprised semi-professional soldiers and small land holders who provided their own weapons and mail, who owed military service to their king or local lord when called upon; the *fyrd* was in some respects the forerunner of the Anglo-American militia.

[94] Rodger, *Safeguard*, 23, 27, 35-38, notes that the Saxon *fyrd* and *scipfyrd* with their broader service base and higher national allegiance were replaced by Norman feudalism, narrowing service to a select professional heavy cavalry and creating myriad local power centers throughout the kingdom under the barons. The Saxon fleet, “one of the most potent symbols of England’s power” withered. Unlike his land forces and castle building programs, William did not incorporate the Saxon or Norse sea-levy into his feudal system, which suggests to the author the diminutive value that the Conqueror placed on standing sea power. He concludes, 49, “It is a striking paradox that the Norman Conquest, made possible by an impressive fleet, caused the rapid collapse of English sea power.”

[95] Campbell, John and Dr. John Kent, in their *Biographia Nautica: Or, Memoirs of Those Illustrious Seamen, ... from the Norman Invasion to the Year 1779, Volume 1* (1785), 57, footnote (f), note that “At this Period, these Officers were stiled [sic] Butsecarles or Butsecarli. In the original, the expression signifies Boat-men.”

offered by free warriors as their national duty survived at least in this nomenclature, if not in practice throughout the Age of Sail.

During most of the Middle Ages the crew of a ship was manned by sailors and oarsmen and was commanded by a single man; the steersman, and later the 'master'. This master often owned his ship as well, although many ships required consensus and profit sharing among the crew to successfully fill her billets.[96] Archers, crossbowmen, and a limited amount of infantry would complete the crew when ships were conscripted for military operations. Masters were most often men of common birth, specialists who learned their trade and navigation practice through apprenticeship and time afloat. These masters were only subordinate to nobility when assembled in a fleet or squadron for war; at that point they still commanded their ships but reported to a noble captain or admiral. It was not until the late Middle Ages that a few subordinate officers and specialists appear on the rolls. The arrival of these specialists (gunners, carpenters, bosons) coincides with the arrival of sea-borne artillery, with larger more complex ship hulls and bracing, and with more intricate sailing rigs.[97] These larger ships, and their formidable military component, saw the first 'captains' in command in the modern sense of the word, late in the fifteenth century.[98] However, the complex technology aboard the ships of the sixteenth century and their longer voyages required an increasingly broad array of specialists requiring craft skills, mathematical agility, and leadership ability. Victualling, maintaining, navigating, sailing, and fighting these vessels in all sea and weather conditions required new social arrangements and organizations, both ashore and afloat. Providing these new institutions,

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Merriam-Webster notes that the word is an "alteration of Old English butsecarl, from (assumed) Old Norse būzukarl, from Old Norse būza buss (ship) + karl man," https://www.merriam-webster.com/dictionary/buscarle

[96] Rodger, *Safeguard*, 137.

[97] Ibid, 138-139, traces aboard larger ships, especially those belonging to the king, clerks or pursers (responsible for victualling and payroll) and master carpenters in the fourteenth century.

[98] Ibid, 160, notes that a medieval captain on land commanded a force roughly equal in size to the force on Henry VII's big carracks. Large ships could have both a captain to command its war effort and a master to navigate and run its basic sea-borne functions very similar to the Iberian practice.

again both at home and at sea, taxed the fabric of late medieval society. Over centuries of fits and starts, what we would recognize as modern bureaucracies and managerial hierarchies evolved to address the challenges of keeping large merchant and naval fleets at sea for long periods of time, equipped for global journeys, and robust enough to ensure the survival of both crews and ships.

Sea service provided the possibility of social mobility for both tradesmen and gentry.[99] Unlike leadership on land, leadership at sea often demanded knowledge of the primary skills of rigging, navigating, or gunnery, but also the active participation of the leadership in time of crises in all tasks required of the seamen. Although 'gentlemen adventurers' often went to sea on great national crusades, and hindered both Iberian and English captains far more than they helped, those gentlemen that chose to make the sea their profession prided themselves on their maritime acumen. As we have discussed, Francis Drake was one of the best navigators of his age, Sebastian Cabot could manufacture his own astrolabes at sea, and Elizabeth's Lord Admiral of England, Charles Howard, "made himself familiar with the seaman's work, 'namely sheet, halliard [sic], bowline, tack and helm'; he could handle navigational instruments and lay a gun himself."[100] The close confines of small wooden ships at sea for months at a time also forced a limited social intercourse between gentry and commoner aboard that did not exist on land.

In the sixteenth century, we begin to see not just regular technical specialists afloat – warrant officers to control the sails and rigging (boatswain) , provisions (purser), guns and powder (master gunner), hull and bracing (carpenter) – but also the development of assistants or

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[99] Rodger, *Safeguard*, 301, notes that "the Elizabethan age was the first in which it became acceptable for young gentlemen to seek their fortunes at sea."
[100] Ibid, 303.

‘mates’ who could act as journeymen in these functions.[101] Landsmen of better birth and education also started appearing as surgeons and chaplains in this period. The master and his mates handled navigation and conning the vessel, while the captain had overall responsibility and specific responsibility for fighting the ship. By the end of the century, we even start to see assistants to the captain – the lieutenant and musketry corporals.[102] The Elizabethan navy did not yet have a stratified officer corps, but technological and logistics demands at sea necessitated a far more complex social milieu than that which had existed in the ships of the Middle Ages. Managing this complex mix required a new type of actor – a man of sufficient stature and social position to command respect in the stratified feudal world, and one technically competent to employ a wide collection of specialists in the best combination to sail and fight his ship.

Once again, the English style of fighting was in large part responsible for enhancing the complexity and size of the technological artifact that was placing such demands on the traditional maritime social structure. Rodger notes that

> “English fighting tactics of the late sixteenth century emphasized a superiority of speed, handiness and weatherliness. They had to fight under full sail, tacking or wearing repeatedly. The best explanation for the changing complements of warships is not so much that the English felt they needed fewer soldiers, as that they needed more seamen as they moved towards a style of fighting based on speed and maneuver.”[103]

The navy also reflected the realities of English society as a whole. In the Stewart period, the division between King and Parliament, state power and trade interests, battle fleets and coastal and trade protection, among others were manifest in the officer corps. Gentlemen captains supporting royal prerogative and power projection contrasted with ‘Tarpaulin’ masters representing trade and aggressive Protestantism. Power shifts over the next several decades

[101] Rodger, *Safeguard*, 320, they also employed a number of “craftsmen and specialists such as cooks, stewards, coopers and smiths.”
[102] Ibid, 309.
[103] Ibid, 313.

would see the rise and fall of Tarpaulin and Gentlemen captains alike. The distinction would not become trivial until well into the eighteenth century, although one could argue it lasted in a less virulent form long after that.

During the seventeenth century naval officer ranks were neither permanent nor of the same social status as army ranks.[104] The rank of lieutenant, previously connected to command of the soldiers afloat, started to gain acceptance and became open as a step to command for gentlemen entering sea service and for accomplished warrant officers alike. Although by no means free of the class consciousness of the larger English society, service at sea did offer opportunity tied to merit which would have been unrecognizable on land. In order to capture, retain, and exploit the talent of its rising commanders, the Admiralty created a system that although not doing away with influence or social hierarchy, did increase the meritocratic basis of promotion at sea. Under Charles II they promoted young gentlemen of high birth to apprentice at sea as midshipmen, under Pepys they tied promotion of anyone to the rank of lieutenant to both sea service and examination, and they created a system of half-pay (first for admirals, then senior captains, and eventually for all commissioned officers) to retain officers when not assigned to seaborne duty.[105] Lastly, and perhaps most significantly, at the dawn of the eighteenth century they created the Navy list; a seniority system for post captains that all but eliminated political influence in promotion.[106] Unfortunately this system did reward inept captains fortunate enough to have been promoted to the list, but this problem was dealt with by

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[104] Rodger, *Command*, 51, notes the example of the Interregnum Nehemiah Bourne who insisted upon being addressed by his middling army rank of Major rather than his navy rank of Rear-Admiral.

[105] Ibid, 121, notes the revolutionary character of Charles II's 'young gentlemen' program. Heretofore it would have been scandalous for young noblemen to be trained in a craft such as maritime navigation or seamanship. The requirements to pass for lieutenant; three years at sea, at least one year serving as a warrant officer, and then a culminating exam was also revolutionary for now blood was not enough – competence and practice had to both be certified.

[106] Ibid, 203, notes a seniority list was assembled in 1691, followed by doubling captain's pay in 1694.

Herman, 205, credits the reforms of Pepys with the eventual creation of the Navy list in 1700.

Anson's innovation of 'yellowing.' Unlike their aristocratic contemporaries in the army or in government, even high-born naval officers prided themselves on their technical capabilities in navigation and seamanship. What we observe with the benefit of hindsight is the evolution of leadership coupled with technical competence as opposed to the classical or medieval notion of leadership as the sole purview of an elite warrior class who disdained commerce or craft as beneath them. However, the changes for common seamen in this century were not so sanguine as they were for the warrant and commissioned officers.

Despite improvements in eighteen century victualling, pay, and medical care, the overriding issue confronting the Royal Navy was raising manpower. Where the critical issue of the seventeenth century Navy had been poverty and its inability to pay its seamen, its eighteenth century problem derived from its financial and operational success, and the subsequently increased demands placed upon it by British society. As ships grew in size and complexity, the relative social position between captain and crew widened. The semi-democratic trading vessels of the Middle Ages and the inherent cooperation and agreement required on the Tudor exploration vessels were essentially extinct. The increasing size of the Navy and its vast number of new berths in times of war made manning the fleet always problematic and often scandalous. Without delving into the history of seaborne service owed by maritime counties to the realm, or with the evolution of impressment with its myriad Parliamentary exclusions, we will just note that even with Britain's relatively large maritime community, it just did not have enough willing and able seamen to man the Royal Navy, its merchantmen, its fishing fleets, and its riverine and coastal trade ships, especially in wartime.

Herman notes that in 1755 the Royal Navy employed 10,000 sailors; five years later in 1760, it had 85,000 seamen on the roles. The total number of active seamen in Britain at the time was claimed to be only 80,000.[107] Of course the definition of mariner can apply to the national number, but not to all those shipboard in the Navy. However the dearth of mariners was substantial and the task of turning landsmen into mariners was time consuming and often forlorn. In order to man its ships the Navy impressed landsmen with no knowledge of the sea, the courts turned out the jails, naval ships recruited (often forcibly) merchants at sea, and ships returning from long multi-year cruises often turned their company over into outgoing ships. The decks of British ships before the mast also became quite cosmopolitan with large numbers of foreign sailors.[108] The English never created a national registration of seamen on the French model; Parliament deciding that press gangs were the lesser evil juxtaposed with a stronger state, temporarily surrendered liberties being preferable to the permanent loss necessary in a state that registered and commanded its entire populace.[109] So Britain struggled throughout the long eighteenth century, until the defeat of Napoleon, with an inadequate manning system and consequently, a far more rigid discipline system than had existed in previous centuries. Landsmen had to be bullied into a trade they were unsuited for and potential deserters had to be discouraged. But one should not imagine that life afloat in the Navy was one of stark misery avoided by any sane being.

Discipline and punishment aboard must be compared to the contemporary standards ashore and not in comparison with today. Rodgers notes that during the Seven Years' War the

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[107] Herman, 295.

Rodgers, *Command*, 319, disputes the number of total mariners, arguing instead that during the War of Austrian Succession and the Seven Years' War, the proportion of the British mariner pool consumed by the Royal Navy was 62% and 67% respectively.

[108] The expression 'before the mast' applies to the seamen. The ship was commanded from the quarterdeck which was to the rear (aft) of the main mast. This space was the purview of warrant and commissioned officers only and was not to be frequented by common sailors unless their duties brought them there.

[109] Rodger, *Command*, 312-316, observes, as do most authors, that the French model actually had more problems manning its ships than did Britain, and only partly due to the priority of the Army within France. Rodger also notes that the liberty question was not a concern over our modern sensibility with personal rights. The real liberty in question was that of the local authorities and their prerogatives in meeting their manning requirements vis-à-vis the authority of the central state and its officers.

Navy had a yearly desertion rate of 7%, but this was mostly attributable to ships turning over their crews at the end of commissions.[110] Eighteenth century British seamen were better fed than their contemporaries ashore and were paid well by the standards of the day, even if only after a ship decommissioned. Adkins in his analysis Nelson's Navy does maritime history a great service by contextualizing the oft repeated stories of brutality in the British Navy by comparing sailor hardships to those on land.[111] He is also keen to emphasize the leadership traits of men like Nelson and Collingwood who husbanded their human resources as well as their ships. He does not stint in giving an accurate description of either punishment or impressment on the negative side of the ledger or the generous prize money (spoils) laws on the other. And it was this last system tracing back to the piratical roots of the Tudor navy that more than anything else encouraged service at sea in wartime. All British sailors shared in the capture of enemy merchantmen and in the destruction of enemy warships. Although the sharing was skewed toward the captain, the officers, and the warrant officers, individual crewman could often earn a year's pay at a stroke serving with a competent and lucky captain. Many men of limited means were willing to take their chances at sea in the hope of getting rich, and both the Navy, especially its cruising frigate captains, and merchant financed privateers recruited at home and abroad for crewman. Famous captains like Thomas Lord Cochrane, 10th Earl of Dundonald, who captured a 32-gun Spanish frigate in the Mediterranean with the 14-gun sloop HMS *Speedy* could even be selective. Successful captains would advertise their openings like entrepreneurs and directly appeal to Elizabethan traditions as Cochrane does below speaking of galleons and Spanish doubloons for the taking. The Navy in general and captains of less notoriety would offer

[110] Rodger, *Command*, 317.
[111] Adkins, 46-47.

signing bonuses, often linked to experience. Even in the Royal Marine recruiting poster below, we see the modern printed broadsheet used, but appealing to piratical prize money as its lure.

Bermuda Gazette, And WEEKLY ADVERTISER

No. 659. SATURDAY, NOVEMBER 12, 1796.

BERMUDA, alias SOMERS' ISLANDS.

By his Honor HENRY TUCKER, Esquire, President and Commander in Chief of these Islands.

A PROCLAMATION.

WHEREAS His Majesty has been pleased, in consequence of the most indubitable Proofs of the Hostile Intentions of the Court of Spain against His Majesty's Dominions, to order his Naval Forces in every Quarter of the World not to neglect any favourable Opportunity that may offer, of attacking the Fleets of Spain, either singly or united with those of France or Holland, or of striking any other Blow at the Possessions of that Crown; And, whereas His Majesty has been pleased further to order, that such his Commands should be made as public as possible within this Colony, to the End that his Majesty's faithful Subjects may be thereby enabled not only to prevent, on the one Hand, any Mischief which otherwise they might suffer from the Spaniards, but on the other Hand to do their utmost in their several Stations to distress and annoy them, by making capture of their Ships, and by destroying their Commerce. In obedience, therefore, to such his Majesty's Royal Will and Pleasure, I do, by and with the Advice and Consent of his Majesty's Council, hereby publish and make known the same; and moreover, I do hereby earnestly exhort all his Majesty's liege Subjects within this Government to manifest their Zeal for his Majesty's Service, by using their utmost Efforts for the Purposes above-mentioned.

Given under my Hand and the Great Seal of these Islands this 8th day of Nov. In the Year of our Lord 1796, and in the 37th Year of his Majesty's Reign.

HENRY TUCKER.

By his Honor's Command,
SAM. ADAMS, Dep. Secretary.

GOD save the KING!

SPANISH WAR.

BOUND on a Cruize of Three Months, and will positively sail on Wednesday the 16th Instant, that new and remarkable fast-sailing Shooner,
FORTUNE OF WAR,
HENRY ADAMS, Commander,
Mounting 10 Carriage Guns, with small Arms, Pikes, Swivels, Blunderbusses, &c. &c. &c.

Those who wish to try their Fortunes against the Enemies of their King and Country, are invited to enter on Board the said Schooner, where a generous Advance and every Encouragement will be given by the Subscribers, at their Store, in St. George's.

GOODRICH and PATRICK.
St. George's, Nov. 12, 1796.

SPANISH WAR.

BOUND on a Cruize, and to sail the twentieth instant that new and remarkable fast sailing Brigantine
PRINCESS ROYAL,
Under the command of that able and experienced Seaman,
DANIEL MORGAN,
Mounting 16 carriage guns, with small Arms, Pikes, &c. &c.

Those who wish to try their Fortune against the Enemies of their King and Country, are invited to enter on Board the said Brigantine, where a generous Advance will be given; also an Encouragement of Eight Dollars to every able bodied Slave, exclusive of the Advance given to their Owners, and in proportion to inferior, by Jeremiah W. Burrows, or Daniel Morgan, at Somerset: and the Subscribers, in Saint George's.

GOODRICH and PATRICK.
St. George's, Nov. 12, 1796.

For TURK's ISLANDS,
The American Brig HECTOR,
JOHN LAWSON, Master,

WILL sail in the course of sixteen days. For Freight or passage, apply to John D. Jennings, supercargo of said Brig; or to the Master, on board, lying at Port Royal.

Spanish, French, and Dutch Commissions for sale at the Printing-Office at 6s, 8d. each.

To be Sold at Public Vendue,
On Wednesday next, the 16th instant,
At two o'clock in the afternoon,
At Mr. Spofforth Bascome's Store,
At the Flatts,
The following ARTICLES, viz.

CALLICOES, fashionable ribbons, checks, brown linen, durants, black shalloon, black lasting, flannels, plain lawn, wildbores, ladies stays, black sattin, mens hats, an assortment of muslins, mens and womens shoes, ravens duck, cambrick, glossinet, broad cloth, perfumery, plated candlesticks, ship compasses, stock locks assorted, carpenters broad axes, lopping axes, marline, window glass, hooks and thimbles, pad locks, scrapers, nails assorted, mustard, whip saws, a small library of well chosen books, &c. &c.

The sale to continue from day to day until all is sold.

JOHN SMITH,
Public Vendue Master.
St. George's, Nov. 12, 1796.

To be Sold at Public Vendue,
On Wednesday next, the 16th of Nov.
At two o'clock in the afternoon,
At the subscribers Office, in Hamilton,
A QUANTITY of IRISH LINENS, and a few Tierces of RICE.

DICKINSON and HINSON,
Vendue Masters.
Hamilton, November 12, 1796.

ENTERED on board the Schooner Betsey, William Moore, Master, in St. George's, a French Boy, who calls himself JEAN, and says he was taken in a French Privateer and is free, and carried into the country; he is about five feet high, yellow complexion, and speaks a little English.

He will be given up to any person who can claim him, on application to the master, on Board. Nov. 12, 1796.

FOR Sale, a Bermuda-bred PONEY, about Five Years old, with a Saddle and Bridle compleat. Enquire of the Printer.

ALL Persons having Demands against the Estate of Mr. THO. CHAPMAN, of Paget's Parish, deceased, are requested to send in their Accounts on or before the 3d of December; and those indebted to the said Estate, are desired to make payment by that time to

SARAH CHAPMAN, administratrix.
Nov. 4, 1796.

For SALE for ready CASH,
A TRACT of LAND, containing twel[illegible] and a half acres, lying in Harris's-Bay parish, adjoining the Lands, of Richard Stecd, Mrs. Alice Peniston, and the late Mr. Joseph Jennings, deceased, and is the land formerly the property of Anthony Collin Peniston, deceased, of Virginia.

A particular discription of the land is thought unnecessary, as it is presumed those inclined to purchase will wish to view it; the price will be made known on application to the subscriber in St. George's.

JOHN GILBERT PENISTON.

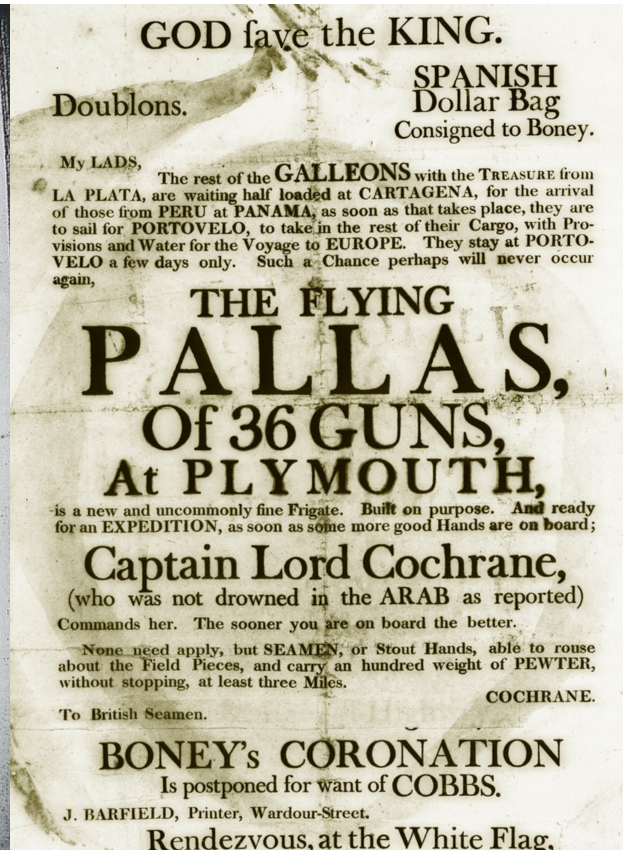

Figure 9.1. Piracy at Sea and Eighteenth Century Advertising.[112] (Upper Left) Bermuda Gazette of 12 November 1796, calling for privateering against Spain and its allies, with advertisements for crew for two privateer vessels. (Upper Right) A recruiting poster by Lord Thomas Cochrane for his 36-gun frigate HMS *Pallas*. He does not need to offer bounties and insists on only skilled hands. Cochrane was an exceptionally successful sloop commander in the Mediterranean during the Napoleonic Wars and extraordinarily popular in the British maritime community. (Lower Left) A Marine recruiting poster extolling Prize Money for service in the War of 1812. (Lower Right) A Royal Navy recruiting poster complete with bounties for volunteering based upon maritime skill for sea service in general.

It would not be too much of an overreach to portray the sea officers of the eighteenth century Royal Navy as a prelude to the professional managers identified by Alfred Chandler in his groundbreaking examination of the nineteenth century Pennsylvania Rail Road Company and the creation of non-familial business management from 1840 until World War I.[113] The social importance of a rising meritocratic professional officer class exemplifies the modern tendency to respect work, technical competence, and leadership and expect their locale in a single actor. As Glete observes,

> "The professional and bureaucratic corps of sea officers was a phenomenon which developed in the permanent navies. These navies had to 'invent' the sea officer in order to create a group of leaders who could combine a socially respectable position (which also gave authority over the crew) with the technical and maritime skills traditionally connected with men of a lower social position."[114]

Eric Ash's examination of the rise of 'expert mediators' in Tudor England combining the social status of their centralizing patrons and theoretical and university knowledge purportedly superior to craft and empirical experience provides an excellent model for analysis of Britain's and America's rising naval commanders. Even young frigate commanders could exercise autonomy of command not available to their seniors in the LOB fleet. Men like Pelew, Cochrane, the

[112] "Commerce raiding," En.wikipedia.org, https://en.wikipedia.org/wiki/Commerce_raiding#/media/File:Bermuda_Gazette_-_12_November_1796.jpg and Royal Museums Greenwich, Prints.rmg.co.uk, http://prints.rmg.co.uk/art/512788/recruitment-poster-for-the-36-gun-pallas-at-plymouth-promising and "Explore Marine Recruitment and more!" Pinterest.com, https://www.pinterest.com/pin/528891549969565070/ and "Explore Maritime Museum, Royal Navy, and more!" Pinterest.com. https://www.pinterest.com/pin/117093659038759713/.

[113] His book, *The Visible Hand: The Managerial Revolution in American Business*, is a set piece of any contemporary graduate course in political economy.

[114] Glete, 49.

young Nelson, Cook, and the American Bainbridge had outsized political, diplomatic, and scientific influence as the modernizing state strove to grow abroad. The Navy Board and eventually the Admiralty were responsible for forming and deploying these leaders and supplying them with compliant if not willing crews. But they also had to supply the ships, keep them in fighting trim, and provide stores and repair facilities across the globe. In short, they had to manage the world's first global logistics organization, and this organization was centered on the dockyards.

Dockyards as Prelude to Industrialization

Like most aspects of the maritime project and modern state building, we can find Mediterranean, and specifically Italian roots. We have already discussed the interaction of Mediterranean and northern ship builders and the adoption of caravel construction techniques, multiple masts, and lateen rigging by the latter and of incorporation of the pintle-and-gudgeon sternpost rudder with corrosive resistant wrought iron fittings, tapered hull-forms aft, and a straight stern post by the former as thirteenth century Italian galleys reignited North Atlantic maritime trade and the northern cogs, first carrying crusaders starting in the twelfth century and later followed by their own Levant trade, entered the Mediterranean (see Chapter 3). However, specific building techniques aside, the Italian shipwrights, especially those in Venice, pioneered dockyard practices that optimized the ship building craft and made the quick assembly, provisioning, and maintenance of large fleets possible.[115] Venice's state Arsenal, 'the Forge of War' was essentially a proto-assembly line industrial complex for shipping.[116] At this massive

[115] Crowley, *City of Fortune,* 278, notes that by 1500 the Arsenal could launch 80 fully provisioned galleys "at a speed and level of consistency unmatched by any rival."
[116] Ibid, 272-282. "The Venetian Arsenal's ability to mass-produce galleys on an almost assembly-line process was unique for its time and resulted in possibly the single largest industrial complex in Europe prior to the Industrial Revolution."

dockyard, the maritime republic assembled its light galleys for war and the multi-purpose ship-rigged great galleys for trade, which also when mounting canon, had great military effect.[117]

The Venetian Arsenal (*Arsenale di Venezia*) was by 1500 a sixty-acre complex of store houses and manufacturing sites, surrounded by a fifty foot tall defensive wall, that not only fabricated all the various parts of galleys (iron, ropes, sails, planking, masts, and rudders), but it also coordinated the end product construction and assembly by moving its galleys in various stages of completion down a central canal to waiting craftsmen for an assembly-line manufacturing operation using standardized parts that predated Henry Ford by centuries.[118] It was not simply a dockyard, but served the ordnance needs and armaments manufacture for Venice's ships, and the victualling of them as well. It stored dissembled galleys for national contingencies and as Crowley notes, "the arsenal worked on a just-in-time basis; it dry-stored all the components of galley construction in kit form for rapid assembly in times of war."[119] This operation had no other medieval equal. One would have to look backwards to Philo's arsenal at the Piraeus or to the Roman Republic's Ostia for anything of comparable size and efficiency. Its size and massive amount of stores astounded visitors well into the seventeenth century and

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[117] Lane, Frederic C., *Venetian Ships and Shipbuilders of the Renaissance*, Chapter 1, provides detailed design differences between the two classes and notes that the great galley was the most secure form of transport in the 14th and 15th century, the high water mark of Venetian galley trade. He also notes, 31, the great military impact the great galley guns had at Lepanto in 1571.

[118] Lane, 129-145, notes that from its foundation (1104) until the fourteenth century the Arsenal only occupied eight acres. The introduction of the great galley and the need for the New Arsenal (1303-1325) quadrupled the size and served throughout the Genoan Wars. When the Turks took Constantinople and started building their own fleets, the need grew. By 1470 the Venetians had added covered docks for all-weather production for eighty galleys and in 1473 doubled the Arsenal's size (the Newest Arsenal) and thereafter maintained a reserve fleet of 100 light galleys, framed, planked, and dry-stored, until the number was halved in 1633. Even after Napoleon's partial destruction of the Arsenal when he conquered the Republic in 1797, only paused the Arsenal's growth. The site would eventually cover 111 acres (45 hectares) or just about 15% of Venice's total area.

[119] Crowley, *City of Fortune,* 280-281. He adds that the Spanish traveler Pero Tafur in the summer of 1436 watched ten galleys get completely assembled in six hours. However, most other sources claim that the Arsenal at peak efficiency could produce a complete galley from scratch in one day, often citing the perhaps apocryphal story of the display presented in 1574 for the visiting French King Henry III (Davis, 4).

Lane, 144, adds that outfitting a skeletal reserve light galley; assembly, caulking, rigging, armed, provisioned and oared, was in fact the demonstration which most visitors would see.

beyond.[120] It also was the largest permanent employer in the Republic or throughout Europe. In the seventeenth century it employed thousands of workers, perhaps as Robert Davis estimates, "ten percent of the city's working population."[121] It also provided a critical role in early labor organization.

Figure 9.2. The Forge of War.[122] The 60-acre walled Venetian Arsenal was the largest pre-industrial period manufacturing operation in the world. Started in 1104 by the maritime republic, the Arsenal was the heart of the Venetian state, navy, and its trade empire. In times of emergency it could assemble a fleet of eighty galleys from disassembled stored components in an assembly-line process using its central lagoon as a conveyor belt which brought the galley work-in-progress to the next specialist crew in line. It also manufactured all the components from rope to rudders needed on a ship; produced naval ordnance, powder, and small arms; built sailing vessels as well as galleys (primarily after 1660), and managed timber reserves.[123]

The Arsenal's two miles of walls and the guild secrecy of its various craft departments (shipwrights (carpenters), caulkers, sawyers, oar makers, etc. – collectively, the *Arsenalotti*) kept not only its process knowledge from its competitors secret, but also prohibited much of its dissemination to its allies or to its satellite arsenals built in its Greek possessions.[124] The

[120] Davis, Robert C., *Shipbuilders of the Venetian Arsenal: Workers and Workplace in the Preindustrial City*, 3-4, notes the comments of English visitors such as John Evelyn and Peter Mundy.
[121] Ibid, 5.
[122] Images from Fishy, Fluffy, "The Venetian Arsenal," Forum.game-labs.net, http://forum.game-labs.net/topic/16367-the-venetian-arsenal/ and "The Arsenal of Venice," Arsenalofvenice.weebly.com, https://arsenalofvenice.weebly.com/.
[123] Lane, 118, notes that the Arsenal was devoted almost entirely to galley construction before 1660 and that sailing ships (often used for trade and called round ships) required "special arrangements" by government to facilitate their construction. He adds, 35, that in 1660 the Arsenal started to build ships of the line. However, before that time, they were instrumental in developing the galleon and the galleass.
[124] Ibid, 57, 72-73, notes that the shipbuilders subdivided into three guilds: ship carpenters, caulkers, and sawyers. The carpenters further divided between those who worked on the light war galleys and those who worked on the great galleys. He adds that these guilds lacked the political power of their brethren across Europe and dealt primarily with social welfare, religious functions, and the promulgation of their craft knowledge.

Venetian state initially appointed a commission of three nobles to manage the Arsenal.[125] As the complexity and size of the operation grew, so did the number of commissioners and the individual power of master carpenters who conducted both state and private business. The English would also appoint commissioners to supervise the private contractors that operated their dockyards. They would reach the great scale of the Venetian operation within their system of yards, if not at one site. When Pepys friend John Evelyn visited the Arsenal, his most vivid impressions were those of scale and efficiency. The English would not emulate the scale of the Arsenal until the nineteenth century, and they could hardly make claims to Venetian efficiency or speed in constructing galleys. However, they were able to build, provision, and maintain a global sailing fleet from their yards with a much higher degree of proficiency than any of their competitors. These yards were a considerable institutional component of Britain's sea power. And these yards had a shaping effect on society which presaged the industrial revolution.

The Navy Board ran a series of Royal dockyards that built a great number of the capital ships of the fleet, maintained its seagoing vessels, and stored decommissioned ships 'in ordinary'. They employed considerable numbers of craftsmen, had intricate supply networks for raw materials spanning numerous support industries, and attracted many private ship building concerns into their orbit. We briefly touched upon the innovations in dry dock technology and its fortuitous use and expansion by the Tudor Navy into the seventeenth century (see Chapter 7).[126] The Tudor and Stewart dockyards in the Thames basin – Chatham, Deptford, and Woolwich – were fine for supporting Calais or invading France through Burgundy, or for

[125] Lane, 129, the Lords of the Arsenal or *patroni* were paid by the state and housed in the Arsenal quarter.
[126] Rodger, *Safeguard*, 377, notes that England was exceptional in its use of dry docks for maintenance and this allowed them to dramatically increase ship life and get far more fighting ships in the fleet for the money spent than their contemporary rivals in France, Holland, or Spain. They started using dry docks for routine Navy maintenance, and in the Royal dockyards had two true dry docks with gates in 1603, which they increased to three doubles and three single docks by 1626. This quadrupled their capacity.

Rodger, *Command*, 233, adds that "Maurepas invested very little in French dockyards, so that large expenditure on shipbuilding was needed to keep up quite a small fleet."

confronting the Dutch, but they were too far from the central Channel or the Western Approaches and the Atlantic for evolving British naval strategy.

Even though the Royal Naval facilities were the best in Europe; they had the most dry docks with four at Chatham alone, strategic changes required the investment of vast sums of money to build new facilities closer to new threats or to support modern doctrine.[127] The failures the Navy experienced protecting its merchant shipping in the wars against Louis XIV demonstrated as Herman notes that

> "The Cruiser Act, its hunter squadrons, faster frigates, and the bombardment of privateer ports would all prove ineffective. Only the maintenance of permanent fleets on station, with adequate infrastructure and facilities, in the Mediterranean, the Caribbean, and North America, would eventually prove effective."[128]

During these seventeenth century wars the Navy Board shifted the fleet headquarters and the maintenance facilities for the active fleet to Portsmouth and the Spithead anchorage. These facilities would support Admiral Herbert's 'fleet in being' deterrent to the French.[129] By 1718 Portsmouth employed 1700 workers and boasted two dry docks and two wet docks.[130] The advent of the Western Squadron strategy pushed a great deal of the fleet further west as the century wore on. Plymouth, the long quiet and ignored West Country port of Hawkins and Drake, experienced a period of explosive growth at the end of the century. In 1691 the Navy Board built the first stone docks in England. By 1720 the facilities covered 40 acres and employed 500 men and as a result of its operations the town of Devonport was created. But the nation's interests were global and moving facilities to the west of England was not enough.

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[127] Herman, 244.
[128] Ibid, 227-228.
[129] Rodgers, *Command*, 298.
[130] Herman, 244, notes it could completely refit ships in fourteen weeks and among other engineering wonders supported a mast pond where fir timbers would be submerged and season for 20-30 years.

The Navy Board also was learning that projecting sea power into foreign seas required a logistical infrastructure in theater. As we noted William III needed to project power into the Mediterranean to shore up his exposed allies, especially the Spanish. And to do this he needed a local base. Rodger notes that

> "With the sending of yard officers to Cadiz in 1694, the Navy Board became an international business for the first time. … Moreover [the dockyards] had a strong multiplier effect on employment, private investment and urban expansion. The dockyards had entered the industrial age a hundred years before the rest of the country."[131]

As the eighteenth century began, the Board created dockyard facilities wherever the Navy regularly sent ships. They established facilities in Gibraltar in 1704 and Minorca in 1708 to secure their operations in the Western Mediterranean and keep the French fleet at Toulon contained. In the 1720s they built Caribbean facilities in Jamaica and Antigua. And in 1749 they built facilities at Halifax to protect the northern fisheries and forests of Maine and to control the Saint Lawrence entrance to French Canada.[132] The Navy Board did not build any eastern facilities as the Indian Ocean and Pacific were the preserve of the East India Company. The corporation fielded its own army and navy to protect is interest along the lines of the Dutch VOC. They also built the only eastern dry dock in 1754. They upgraded it to a double dock during the Seven Years' War and tripled it by 1773. Although not a Royal dockyard or Navy Board facility, Royal Navy ships in the region used these facilities regularly.[133]

Despite the early reluctance of other European navies to embrace dry dock technology, they did invest heavily in dockyards at home and overseas. They even built dry docks, but

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[131] Rodger, *Command*, 189.
[132] Dull, 36, and Herman, 245.
Robson, 49, notes that although France ceded Nova Scotia to Britain under the terms of the Treaty of Utrecht in 1713, the British did not settle immediately. It was only after the Treaty of Aix-la-Chapelle of 1748 restored Louisbourg to France, that Britain realized they needed a local port to protect their fisheries.
[133] Rodger, *Command*, 304.

throughout the eighteenth century they lagged behind the British in numbers and technical capability. The lifespan of wooden ships, especially those long at sea and notably before the innovation of coppering the bottom to protect it from the teredo worm and to decrease the friction caused by dirty hulls, was not long if left untended. The Spanish initiated a fleet rebuilding program from 1714-1754.[134] They invested in dockyards to increase the lifespan of their ships, foremost in Havana, to support a permanent squadron of large, strong, lightly armed ships intended for long-range cruising and silver escorts, not for fleet actions. These *guarda-costas* would eventually provide Britain with its *casus belli* and cost Jenkins his ear, but their Havana dockyard was extremely successful.[135] The French also invested in dockyards and limited dry dock facilities, but once again, as during the time of Louis XIV, a disproportionate amount of their funds were spent of new ships rather than on infrastructure. This failure to recognize the holistic nature of sea power and the essential roles played by both maritime trade and fishing communities and by logistical infrastructure would greatly impede their operational effectiveness throughout the long eighteenth century.

What was true for all these Atlantic naval states is that naval investment had a dramatic effect on the growing economic integration and wealth of the age. Britain employed 2-3,000 men at its Royal dockyards in 1688. By 1814, it employed more than 15,000 workers – 4,200 at Portsmouth and 3,800 at Plymouth. Dull notes that “the great French and English dockyards, with their building slips, dry docks, storehouses, and manufacturing facilities, became the largest industrial establishments in Europe.”[136] The social change here was far greater than the scale of

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[134] Rodger, *Command*, 232-233, notes that their navy was charged with preserving their two empires in Italy and the Americas and to do this they chose to build ships that could protect their sea lines of communication and to provide a counterweight that would balance the power between France and Great Britain as an ally, acknowledging that they alone would not be able to beat either.
[135] Dull, 38, the Havana dockyard used Cuban cedar and mahogany which turned out to be far superior to oak which produced ships with a lifespan of only 12-16 years prior to needing rebuilding.
[136] Ibid, 15.

the projects or the number of workers involved. Dockyard work was a combination of craft and manufacturing. It was proto-industrial in that workers were paid for their time, not for the end product. Britain's maritime requirements initiated the migration from farm to urban workplace that would become emblematic of the Industrial Revolution of the nineteenth century. It was a migration on a smaller scale, but it was a harbinger and a testing ground. But this workplace change did not only impact workers on the yard. Just as the supply chain that grew up around victualling favored large capitalist concerns, the Navy Board had a similar impact on the businesses concerned with the supply chain for naval stores.

In British facilities, the Navy Board fostered a competitive market with numerous 'standing contractors.'[137] They developed a 'naval industrial complex' centered on their Royal yards and large favored contractors would be rewarded with regular business if they met the auditing standards enacted by the commissioners and descended from Pepys. The Board preferred not to use privately owned shipyards for their larger warships or for maintenance, but Britain's large merchant class also demanded large numbers of ships which created a large ship-building reserve capacity in Britain. In times of crises, the Board often had to turn to private contractors for cruisers – sloops and frigates, and these yards proved to be a major British asset in its naval wars (see Conclusion). This economically virtuous cycle was highly simulative. Contractors supplied stores for the dockyards from a global trade network for which they needed ever larger and more numerous ships to support. This trade needed a larger navy to protect it which put new stress on the yards and the supply contractors. The private yards might have been cheaper than the Royal yards, but the demands and expertise of those facilities controlled by the Board kept the supply chain funded as they had vast regular amounts of government money to

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Herman, 186, notes that the Navy was crucial to seventeenth century English economy in that the "four royal dockyards were the largest single employer in England."

[137] Rodgers, *Command*, 301-303.

spend, which itself grew with the growth of custom dues and excise. One does not need to embrace Keynesian economics writ large to accept, in at least this late mercantilist phase of Britain's evolving economic system, that the Navy Board was in fact propelling the growth of a host of maritime trade businesses.

The Royal yards might be rife with graft and ancient privileges like taking 'chips' (in theory loose lumber) and 'extras' (excessive overtime pay), but the Board preferred to control the maintenance process and the evolution of ship design. Overall, Rodgers contends that the "yards worked well, but they did not work hard."[138] They also made incremental technical improvements which steadily increased the Royal Navy's superiority over its European rivals. And even though French spies could copy British innovations like improved tar or lighter blocks, they were unable to implement them without the supporting maritime community and culture that produced them.[139] And Britain's Navy Board was actively involved with and heavily influenced by this maritime community.

There are several questions to ask concerning the maritime influence upon modern industrialization. Did the enormous ship building enterprises of the late medieval Mediterranean and early modern period Atlantic powers presage modern industrialization? Navy yards in both old and new worlds, from India to Philadelphia became the largest single employers of the age. Also, did the exigencies of maritime power create the demand for facilities within these dockyards that could address the thoroughly modern demand for mass produced uniform

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[138] Rodger, *Command*, 299-301.

[139] Ibid, 302, notes the Navy Board sea trials for improved tar (1752-55), and machine-built better and smaller blocks (1759 – Walter Taylor). "It was precisely such incremental technical improvements which contributed so much to the superior performance of British ships, and it was typical that in spite of the fullest information supplied by French naval espionage, including examples of the machines themselves, the Taylor system was not made to work in a French dockyard until 1795."

interchangeable parts?[140] Although Mokyr dismisses Brunel's block manufactures at Portsmouth as nontransferable to future industrialization in Britain due to their highly specific use for a single consumer (the Royal Navy), he cannot dismiss the intellectual impact that this steam driven, machine tooled factory had upon the future pioneers of British industrialism.[141] Other scholars go further, arguing that

> "The Portsmouth Block Mills form part of the Portsmouth Dockyard at Portsmouth, Hampshire, England, and were built during the Napoleonic Wars to supply the British Royal Navy with pulley blocks. They started the age of mass-production using all-metal machine tools and are regarded as one of the seminal buildings of the British Industrial Revolution. They are also the site of the first stationary steam engines used by the Admiralty."[142]

Perhaps it is arguable that the colonial byproducts of the Atlantic powers oceanic programs themselves provided the conditions hitherto missing to make an industrial revolution anywhere possible. In his comparative study of European emergence and Indian and Chinese eclipse, Kenneth Pomeranz makes the argument that:

> "One core, Western Europe, was able to escape the proto-industrial cul-de-sac and transfer handicraft workers into modern industries as the technology became available. It could do this, in large part, because the exploitation of the New World made it unnecessary to mobilize the huge numbers of additional workers who would have been needed to use Europe's own land in much more intensive and ecologically sustainable ways."[143]

Another question to ask is if the technology applied to the oceanic program and its land bound uses had in them enabling properties speeding western industrialization.

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[140] Similar demands upon land faced the armory complexes of Enlightenment and Revolutionary France and the Harpers Ferry and Springfield Armories of early nineteenth century America as addressed by Ken Alder and Merritt Roe Smith respectively.
[141] Mokyr, 185.
[142] Coad, Jonathan, *The Portsmouth Block Mills: Bentham, Brunel and the start of the Royal Navy's Industrial Revolution*, London: English Heritage, 2005.
[143] Pomeranz, Kenneth, *The Great Divergence: China, Europe, and the Making of the Modern World Economy*, 264. He makes the further argument, 297, "Thus, forces outside the market and conjunctures beyond Europe deserve a central place in explaining why western Europe's otherwise largely unexceptional core achieved unique breakthroughs and wound up as the privileged center of the nineteenth century's new world economy, able to provide a soaring population with an unprecedented standard of living."

> "As Mokyr puts it, Europe's real technological edge in the eighteenth century – and Britain's within Europe – was not in tools or machines, but in instruments – clocks, watches, telescopes, eyeglasses, etc., though these gadgets had some application as producer goods – principally in ocean-going navigation."[144]

What we have observed is that the growth of the maritime project stimulated growth economically and organizationally, and it is logical to infer that reciprocal influences between the maritime project and the evolution of the institutions of modernity tied to this economic and organizational development like Britain's industrialization process are valid. The mass production of textiles by steam driven looms in large factories would have been a hard to imagine without the global supply network created by Britain's mariners, the excess capital created by its trade seeking investment opportunities, nor without its naval and merchant fleets on hand to protect and deliver that product to far flung consumers. The Royal Navy, through the auspices of its Navy Board, also controlled a vast global network of naval and maritime stores and natural resources and it did this through its Royal dockyards.

Naval Stores and the Management of Natural Resources

Not only were sailing ships of the eighteenth century the most complex mechanical devices yet devised by man, they were voracious consumers of a wide array of natural and manufactured resources. This was especially true of men-of-war. Great nautical empires from the Athens of Themistocles to the Venetian Republic, although made at sea, first required the resources of the land.[145] When these resources were exhausted, decay and retrenchment often

[144] Pomeranz, 67. However he notes that, early "military spillover" technological development – "advances in food preservation made in the early nineteenth-century Royal Navy … such advances were relatively rare." (194)

[145] Hale, John R., *Lords of the Sea: The Epic Story of the Athenian Navy and the Birth of Democracy*, XXV, notes that the Athenians who created the first Thalassocracy made a conscious decision to make their fast triremes durable not with metal sheathing but with nightly beaching and vast quantities pitch and tar. In addition to forests, Athens required a large supply of these products and their trade network assumed strategic as well as economic importance.

Lane, 122, notes that in Venice, an exclusive forest owned by the Arsenal navy, in the Montello hills area of Veneto, provided the Arsenal's wood supply. Like the forests of early modern Britain, these were properties of the state, managed by the Navy. He adds, 220-221, that oak groves being critical to ship building and the quickest to quickly followed. Or as in the case of Attica or Venice, these people expanded their trade networks to secure access to larger and more dispersed resources. However, naval supremacy and extensive maritime trade required not just access, but judicious management of natural resources. In this sense, Britain as guided by Parliament and the Navy Board of the seventeenth and eighteenth centuries rose above the practices of its nautical forebears and ushered in both a modern's appreciation for conservation and an economist's judicious dispersion of production and supply.

We can observe the attempt by England's national thought leaders to tie together the preservation and wise use of forests as early as Tudor times when Dr. John Dee disrupted the Spanish plot to burn the New Forest with an explicit goal of damaging the English ship building effort (see Chapter 7). This is the same New Forest (South Hampton) timber resource that was essential in answering the naval ambitions of Henry Tudor. As Konstram notes,

> "A ship the size of the *Sovereign* would have needed approximately sixteen hundred tons of oak to build, a mixture of seasoned and unseasoned timber. That was the equivalent of twenty acres of prime, mature woodland, and all that timber would have to be cut, trimmed, stacked while it seasoned, then transported to the shipyard." [146]

In the seventeenth century, John Evelyn's tract *Silva* explicitly calls on the state to husband its forests at home and abroad by encouraging private and colonial tree growth, if for no other reason than to maintain its naval power. As a past visitor to the Arsenal and a great admirer of its scale and efficiency, it is not unlikely to suppose that Evelyn was influenced by the Arsenal's forest management policies, its tree census, and its planting programs (see footnote 120).

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become exhausted, led to state policies to conserve and increase such groves between 1470 and 1492. All oak trees had the protection of the navy and local villages had to conduct a detailed tree census. As the demand for ships grew with the Turkish threat, so did the scope of timber lands under direct control of the Arsenal.

Braudel, 142-143, notes the many wood types needed for galley construction and the almost frantic search for fleet timber that even caused trees in Poland to be designated for use in the Spanish Armada. Eventually a timber crisis in the Mediterranean can be tied to lower average ship tonnages of succeeding generations.

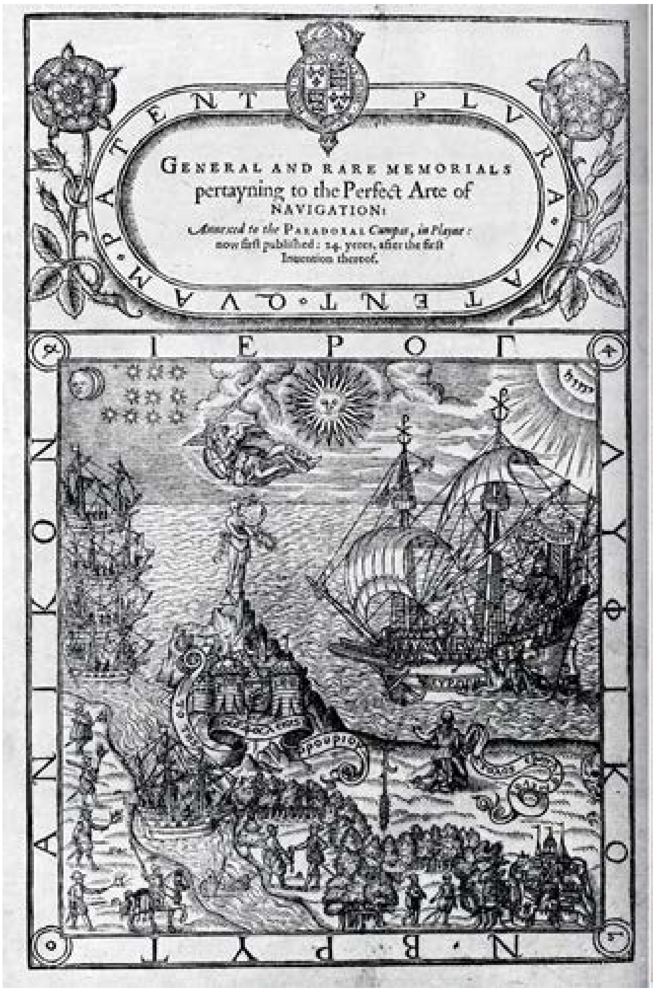
[146] Konstam, *Sovereigns*, 36.

Of course navies comprised of wooden sailing ships would be dependent on trees, but the scale was staggering. A single ship of the line required as many as 3,000 trees of very particular quality. The Royal navy only used English Oak (*quercus robur*) for king's ships. These ships needed old trees grown in the open that were knotty and bent to use for knees or internal ribs and braces. It also needed straight trees raised in groves for the masts and yards. Herman notes that "England's entire forest industry was in the hands of the navy."[147] The shipbuilders of both private and Navy Board dockyards travelled regularly to England's forests to select their trees. As these journeys grew in distance as local resources withered, so did the transportation networks designed to get timber to the yards.

[147] Herman, 186.

Lane, 217-218, in his observations on Venetian forestry management and ship building techniques, notes the same pattern. The hulls of their galleys were built of oak. Curved tree parts served as ribs for the hull. For the stern and stern post straight trees members were used. For masts and spars, straight fir trees were used.

Mott, 133, notes in a similar vein that identifying trees for the shafts of the enormous galley quarter rudders (in some cases over 10 meters long and weighing several tons) was particularly hard in the Mediterranean as the ideal trees – oak, mahogany, and holly – did not grow particularly straight there.



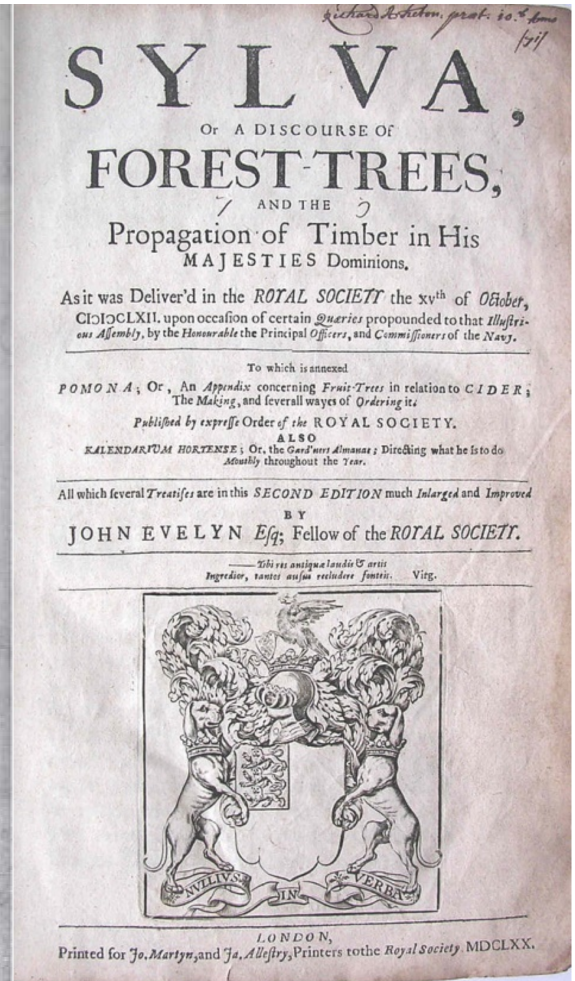

SYLVA,
Or A DISCOURSE Of
FOREST-TREES,
AND THE
Propagation of Timber in His
MAJESTIES Dominions.
As it was Deliver'd in the ROYAL SOCIETY the xv[th] of October,
CIↃIↃCLXII. upon occasion of certain Quæries propounded to that Illustrious Assembly, by the Honourable the Principal Officers, and Commissioners of the Navy.
To which is annexed
POMONA; Or, An Appendix concerning Fruit-Trees in relation to CIDER; The Making, and severall wayes of Ordering it.
Published by expresse Order of the ROYAL SOCIETY.
ALSO
KALENDARIUM HORTENSE; Or, the Gard'ners Almanac; Directing what he is to do Monthly throughout the Year.
All which several Treatises are in this SECOND EDITION much Inlarged and Improved
BY
JOHN EVELYN Esq; Fellow of the ROYAL SOCIETY.
—Tibi res antiquæ laudis & artis
Ingredior, tantos ausus recludere fontes. Virg.
NVLLIUS IN VERBA
LONDON,
Printed for Jo. Martyn, and Ja. Allestry, Printers to the Royal Society. MDCLXX.

Figure 9.3. Two Maritime Treatises with Conservationist Underpinnings.[148] John Dee, *The Perfect Arte of Navigation* (1577), argues for among other things state protection of the nation's fisheries and forests (left); and John Evelyn, *Sylva or A Discourse of Forest-Trees* (1664), argues for private tree growth for supplying the Royal Navy with timber (right). Evelyn's paper was presented to the Royal Society and attendees from the Navy Board on October 15, 1662.

Maritime forest management and depletion in England had a number of less direct, but equally important transformative impacts on a wide array of societal factors. On the mathematical and scientific front, Rodger observes that "Dockyard officers were involved in developing the new logarithms, which allowed mathematical techniques to save the errors (and waste of timber) consequent from geometrical scaling up from plans."[149] Tree depletion also

[148] Images from Writeson, Maegan, "The Perfect Arte of Navigation," Olneytempest.wordpress.com, https://olneytempest.wordpress.com/2014/07/02/the-perfect-arte-of-navigation/ and "John Evelyn," En.wikipedia.org, https://en.wikipedia.org/wiki/John_Evelyn.
[149] Rodger, *Safeguard*, 388.

limited charcoal available forcing iron mongers to turn to burnt coal or coke. The increased forge heat possible with these alternatives was transformative in nascent industries. And lastly, the need for maritime stores of all types expanded global trade volume.

Mast timber demand spurred increased North Sea and Baltic trade. The Navy Board turned to Sweden for pitch, tar, and bar iron. It procured timber from the eastern Baltic ports of Russia, Poland, and Prussia. It obtained its softwood timber and small masts from Norway.[150] Cordage, hemp, and the various grades of sail cloth also had extensive Baltic networks. Unfortunately for Britain, its close access to the Baltic and its building reliance for its maritime capabilities made it vulnerable to political shifts or price fixing within the region.[151] Britain's reaction to this specific threat had great impact on the development of economic capability in its North American colonies and the stirring of independence movements. When the Great Northern War commenced at the dawn of the eighteenth century, Britain had already turned its attention westward.

When William and Mary reorganized the Massachusetts Bay Colony, an area that stretched from the borders of New York, through Maine, and into Nova Scotia, in 1691 they did more than limit local governance and appoint its Crown Governor. We can turn to the last clause of the charter to see the influence of the Navy Board and its voracious appetite for timber. It asserts Royal prerogative over mast timber as emphatically as any Tudor monarch,

> "And lastly for the better provideing and furnishing of Masts for Our Royall Navy Wee doe hereby reserve to Vs Our Heires and Successors all Trees of the Diameter of Twenty Four Inches and upwards of Twelve Inches from the ground growing vpon any soyle or Tract of Land within Our said Province or Territory not heretofore granted to any private persons And Wee doe restrains and forbid all persons whatsoever from felling cutting or

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[150] Rodger, *Command*, 302-303.

[151] Ibid, 191, notes that a last of tar [12 or 14 barrels] from the Baltic rose from £6 to £36 in 1704 during the Great Northern War. As a result Parliament passed the Bounty Act which among other things provided subsidies for the greatly inferior and more expensive New England tar. These subsidies spurred the growth of an industry that over time improved the quality and lowered the cost of its product.

destroying any such Trees without the Royall Lycence of Vs Our Heires and Successors first had and obteyned vpon penalty of Forfeiting One Hundred Pounds sterling vnto Ous Our Heires and Successors for every such Tree soe felled cult or destroyed without such Lycence had and obteyned in that behalfe any thing in.Belonging to the Navy Board's select group of suppliers was a position sought by many in the colonies and at home."[152]

This assertion of rights to any tree of a diameter above twenty-four inches was specifically targeted at the White Pine (*Pinus strobusand*) and was intensified by the New Hampshire General Court in 1722 by claiming specimens as small as twelve inches in diameter.[153] Parliament codified this dimension in 1772 in the Timber for the Navy Act claiming specifically that any White Pine with these dimensions was the property of the King. His deputy surveyor would scour both common and private land, and on occasions mills, to blaze the broad arrow on any tree meeting this criterion. The broad arrow was a symbol of Royal ownership with a legacy that also traced its origins to Henry VIII and his Ordnance Board. Needless to say, the claims of a distant monarch to the trees in one's backyard were a distinct irritant to independence minded colonists.

Shortly after passage of the Timber Act, colonists in New Hampshire initiated one of the first rebellious actions of the American Revolution, the Pine Tree Riot of April 1772.[154] They took the White Pine as their symbol and emblazoned it on a field of white. This flag, often including the phrase "Appeal to Heaven [or God]" referenced John Locke's refutation of the

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[152] "1691 Charter of Massachusetts Bay Text and Words," Landofthebrave.info, https://www.landofthebrave.info/1691-charter-of-massacusetts-bay-words-and-text.htm.

Rodger, *Safeguard*, 388, contends that the creation of the Maine colony was specifically driven by the timber needs despite the early claims of Massachusetts. From its onset the Navy owned every tree greater than twenty-four inches in diameter.

[153] This action of 1722 followed an earlier Parliamentary Act of 1711.

[154] Since the original defendants (residents of Weare, NH) in the Pine Tree Riot case were clearly guilty of felling large marked trees, and since they all plead guilty, it is obvious that they had public sentiment on their side since each was fined only 20 shillings (£1) and court costs instead of the huge fines prescribed (up to £100 per tree).

divine right of kings and the right of just rebellion.[155] A flag similar to this is reported to have been flown at the Battle of Bunker Hill three years later.

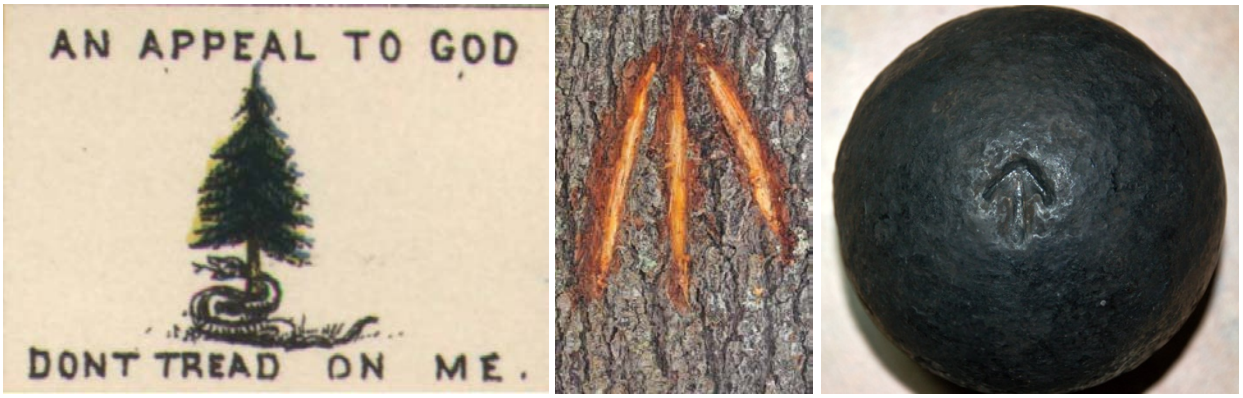

Figure 9.4. The White Pine Tree Flag of Liberty and the Broad Arrow.[156] The appetite of the Royal Navy for timber, especially mast timber, helped ignite rebellious passions in the New England colonies. Surveyors claimed every tree greater than twelve inches in diameter as Royal property. This encroachment of local liberty symbolized by the broad arrow blaze and the heavy fines for felling marked trees inflamed growing local resentment of distant rule. The broad arrow symbol can also be seen here on a piece of shot from Fort Niagara, as it was on all Royal ordnance.

Although resentment at tree policy was important, not all colonists resented the Royal Navy and its prerogatives. A number of local men saw the great opportunity for local industry and commerce that could come from being an active participant in this system. Being on the Navy Board's approved list of suppliers for maritime stores and shipping was something many men sought. Even the arch-antiroyalist Oliver Cromwell was himself as timber supplier to the Navy.[157] Many in New England wanted to open the region up as both an alternative source of supplies to the Baltic and as a shipping producer in its own right. Parliament and the Navy Board made this possible by subsidizing the local pitch (tar and resin) industry despite its high

[155] Locke, John, *Second Treatise on Civil Government*, 1690.
[156] Images from "Flags + Heraldry," Pinterest.com, https://www.pinterest.com/igorsimic/flags-heraldry/ and Boothbayregister.com, http://www.boothbayregister.com/sites/default/files/2013/08/field/image/Maine's%20Biggest%20Timbers%20-%20kings%20broad%20arrow-300dpiWcullina%20(2).jpg and "Ordnance Depot," Maritimearchaeology.com, http://www.maritimearchaeology.com/information/bombs/.
[157] Rodger, *Command*, 44.

local production cost and comparably inferior quality.[158] One such elegant colonial pitch for this business was delivered by the Governor of the Connecticut colony John Winthrop [the Younger], FRS, by using the auspices of the Royal Society and the close relationship it had with the Royal Navy and members of the Navy Board.[159] To examine this appeal we must return to the Classified Papers of the Royal Society.

Winthrop presented his case for building a colonial shipping industry capable of supporting the Royal Navy in the early 1660s at the beginning of the Restoration and upon the ascension of the nautically minded King Charles II. His case is detailed, well targeted to his audience, and decades ahead of the political necessities that would make the Navy Board's westward expansion utterly necessary. He presented his purpose directly,

> Concerning ye [the] Building of shipping in New England. 2 pp. Sept. 24
>
> "The honorable Society may be pleased to consider whether it may not be fit to propose to his Maty [Majesty] or hi[s] honorable Commissioners for the Navy the convenience of building of ships in some of the Northern parts of America there being several reasons it may be proposed of as motives encouraging those unto thoughts.[160]

His first set of reasons expound on the natural resources available,

> .
> (1) That there is great store of good oak timbers fit for the building of shipping in many parts of that continent.

[158] Rodger, *Safeguard,* 302. He also notes that the Navy was interested in New England primarily as a source of great masts for its larger ships.

[159] The elder John Winthrop was one of the Puritan founders of the Massachusetts Bay Colony and served as its 2nd, 6th, 9th, and 12th Governor. He is renowned for his "city upon a hill" allusions. His son, John Winthrop, was born in England and was both well-travelled and educated. He served as Governor of Connecticut in 1657 and was reelected annually from 1659 until his death in 1676. He was also elected a fellow of the Royal Society during his visit to England from 1661-1663. In addition to his interests in the natural sciences and botany he also practiced astronomy. He made an early claim in 1664 to sighting a fifth moon of Jupiter. Edward Barnard of the Lick Observatory confirmed the existence of the moon in 1892. Winthrop had two papers published in *Philosophical Transactions*: "An Extract of a Letter, Written by John Winthrop Esq; Governour of Connecticut in New England, to the Publisher, Concerning Some Natural Curiosities of Those Parts, Especially a Very Strange and Very Curiously Contrived Fish, Sent for the Repository of the R. Society" (Phil. Trans. January 1, 1670 **5** 1151-1153; doi:10.1098/rstl.1670.0015) and "Description, Culture and Use of Maize." He met King Charles II and presented him with New England flora during his visit.

[160] Winthrop, John, "Concerning ye [the] Building of shipping in New England. 2 pp. Sept. 24," *The Early Letters and Classified Papers, 1660-1740*, Reel 16, Volume VII (1), paper #11.

> (2) There are great store of pine and fir trees fit for masts of all sizes for ships of any burthen.
> (3) There is store of that sort of pine which is called pitch pine of which tar and pitch may be made.

After enumerating the oak (for hulls), the pine (for masts), and pitch (for caulking) available, he goes on to describe the local milling technology onsite that will not only process the raw timber for local construction in a cost effective manner, but that will also make its shipping practical.[161]

> (4) There are many sawmills for the sawing of plank and board of all sorts, so that there may be a sufficient quantity at all times provided [,] though there should be divers [numerous] ships built at a time.
> (5) In respect of the cheapness of Timber and by the help of those sawmills, which are most of them upon or near good harbor and navigable rivers [,] plank will be much cheaper then [than] it can be produced in England, possibly for a ship, or found part of the price.

Lastly, he makes his case for his region not just as material supplier, but as producer. He recites the accomplishments of the local ship builders over the past two decades. He lists the variety of the local craftsmen and the full panoply of ship building and rigging skills they have mastered. And he notes that they have accommodations for English craftsmen if any are required.

> (6) It is not a new project ye [the] building of shipping in these parts, for there hath bin [has been] sufficient experience already made there having bin [been] every year some built (great or small) for about these twenty years. There were this summer divers [numerous] keels at London that were built there, where of two were of about 200 tunnes [tons], there is one now of an hundred tunnes [tons] in this River [the Thames], that was built there. There have bin [been] formerly some of 300 and 400 tonnes [tons] built there. …
> (7) … there being there already very good artists for Masts workmen on other ordinary work for building of ship[s] known well to many here all for also kalkers [caulkers] … and smithes [blacksmiths] and all other trades …
> (8) When ye [the] ship is built it may be preframed first with plank boards, Kne[e] timbers, or other timber, & … or with several masts, all which will be of good … of building ships here.
> (9) When it shall be thought fit to send over more workmen there are houses for … lodging for there [their] entertainment … and plenty of all sorts of provisions for ye [the]

[161] Tar was produced by burning pine branches and logs very slowly in kilns. It was applied in coats Seamen painted to the ship's rigging. Pitch was manufactured by boiling tar to concentrate it. In addition to its use for caulking the seams of deck and hull planking, it was painted on the sides and bottoms of non-coppered wooden ships to make them watertight. It had to be heated to increase its viscosity for application.

> supply of as many as it may be necessary be imployed [employed]. … Such things as … hence forward of business if only Rigging, Sayles [sails], Anchors, Cables and … Spanish Iron for spikes … for though there be Iron works, and good Iron made there, yet Spanish Iron is most approved for that work.

Winthrop's vision is that of the colonies as an integral economic part of the maritime industry that had been developing since the sixteenth century. Although he secured a Crown monopoly on iron works after his 1641-1643 visit to England, he did not see Connecticut rise as a Royal Navy ship builder. Regardless, Winthrop did not see the colonies as a mercantile outpost established simply to harvest timber for the mother country. He was fully embracing the new culture created by the maritime project in all its guises from science to commerce to naval issues, and wanted his colony to have its role in its further evolution. Sadly, the modernizing impulses so much at the heart of the maritime culture, could not assure good policy in the larger society.

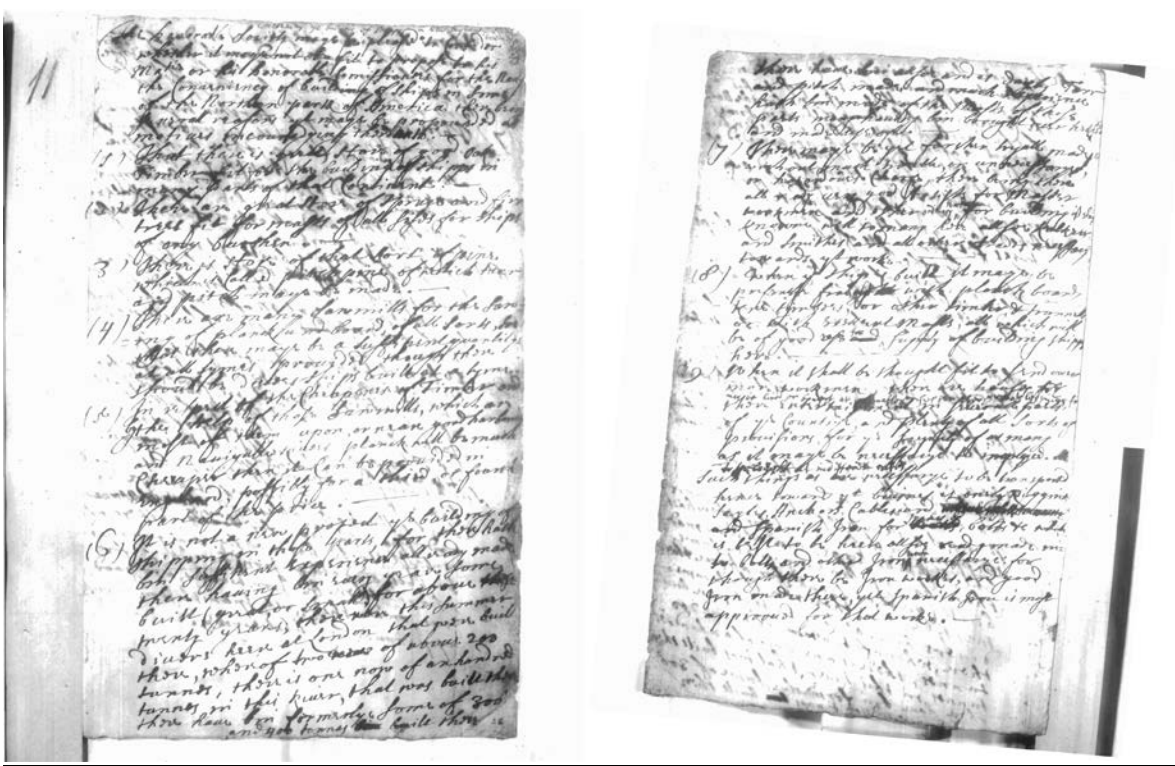

Figure 9.5. John Winthrop's Proposal Concerning ye Building of shipping in New England. This proposal to the Navy Board in 1661 was channeled through the Royal Society in an attempt to exploit the close relationship between the two and their ongoing collaboration in expanding both navigation and natural science. This detailed plea to position New England firmly in the English maritime community as ship builder and intricate part of the naval stores supply chain as opposed to mercantile supplier of raw materials was never fully headed.

It is written in 'Very Cursive Late Secretary Hand.' The following observations will aid transcription:

“e” looks like “r”; at word endings sometimes a “y” - conveniency [convenience]; “y” used for “i” sometimes – tyme, tymes; “j” as well – tryall; Capital “C” more like an “L”; “s” occasionally looks like lower case “f” – possibly; “w” looks like “m” – new; “m” looks like “w” sometimes; “y” used for “th” in ye [the] – Thorn: “th” is the Saxon letter “y”; Capital “I” looks like cursive capital “J”; Lower case “t” almost never crossed; Odd lower case “p” – looks like lower case cursive “j” – ‘pine’ looks like ‘from’; Bleed through from back of page lighter and should be ignored; and Tails from letters from upper lines often given spaces in middle of words below.

As the eighteenth century progressed, the Royal Navy’s insatiable appetite for timber and pitch exhausted useful pine reserves in New England and its attention moved southward to the Carolinas and Virginia. The Navy’s many operations in Charleston, South Carolina, headed personally by a young Captain George Anson were so successful, and such a boon to the local economy, that the city still preserves his name in its first suburb Ansonborough and the area’s main streets (George and Anson).[162] Shipping facilities from Charleston to Halifax were in fact created along the Eastern Seaboard, both to support local commerce and to supply the Royal Navy, as the young American Republic followed her rejected mother country in developing a modern state stimulated by maritime trade and the new capitalist spirit of the Age. One of Captain Cook’s early commands, the schooner/brig *Grenville*, was built in Massachusetts and launched in 1754.[163] Before the Republic severed ties with Great Britain, she was in fact fulfilling Winthrop’s vision and producing shipping not just for her own growing trade, but for the Royal Navy.

Connections

Jan Glete has observed that, “The role of navies in the state formation process has often been neglected to that of the armies.”[164] This chapter has explored that contention. While we have traced the multiple aspects of the maritime project and its communities and culture on the

[162] Anson captained two ships from 1724 to 1745 with the mission of protecting the Georgia and Carolina coasts from pirates and the Spanish. There are apocryphal stories that he won the 64 acre tract in a game of cards. Regardless, when he returned after his circumnavigation, he used a good part of his prize money to layout the streets and build houses.
[163] Robson, Appendix I.
[164] Glete, 63.

development of the modern English state in previous chapters, it is clear that the impact of the Royal Navy on the evolution of modern Britain was indeed large. In its wars against France and Spain, Britain protected the interests of its maritime community and merchants. It adapted its policy to expand and protect global trade. To do this it had to field a navy with global reach and staying power.

To achieve this objective, Britain created large complex bureaucracies and an intricate logistics network which was an economic system unto itself. It adopted steady taxation and devoted the proceeds reliably to naval infrastructure regardless of the swings in its new party politics. It created short-term debt instruments linked to the future proceeds of this taxation and a market to trade and assess bond risk. The emerging naval industrial complex of technically competent career civil servants, industries devoted to the navy, and the direction of a complex agricultural market would become emblematic of emerging modernity. Welfare organizations for naval veterans including the naval hospital system, pensions for widows, and the ameliorative projects of the Sick and Hurt Board ashore and at sea were also novel and trend setting.

The creation of the professional sea officer foreshadowed the rise of technically competent and socially respectable middle class management. The professionalization of the Royal Navy's officer corps including its midshipmen training program, its sea competency and time requirements for lieutenants, the requirement to pass examination for promotion, and the captain's seniority lists did not eliminate the impacts of influence and birth, but they certainly laid the groundwork for creating a truly modern meritocracy. Although family and political connection was still exceptionally important, the Royal Navy of Anson and Nelson could boast a post captain who was the son of a slave and admirals who started their service as common sailors with no family connections whatsoever.[165] The great Pacific explorer Captain James Cook, the son of a farm laborer, began his career as a common sailor on colliers in the North Sea, started his Royal Naval career as an able seaman, and became the most distinguished navigator, naval astronomer, surveyor, and frigate commander of his generation.[166] The exceptional performance of the Royal Navy vis-à-vis its competitors over the long eighteenth century, was exemplary. The high regard with which it was held by both political parties and populace alike not only secured it long-term consistent government support which its adversaries could only envy, but this regard produced leadership practices open to imitation. This was true not just in the nascent American Navy, but within British society as a whole.

Lastly, the dockyard operations of the Navy Board were proto-industrial and presaged the coming tectonic social shift of Britain's Industrial Revolution of the early nineteenth century. As we have observed, the needs of the Navy and the maritime trading culture were fostering the creation of the largest manufacturing operations in the world. Not only was the work highly complex and supported by a vast logistics network, but the operations required enormous social change. The seasonal rhythms of agricultural work were being supplanted by the foreman's

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[165] Herman, 242, notes the story of Captain John Parkins. The son of a slave and most probably a slave himself, Parkins started his nautical career as a pilot. He commanded the brig *Endeavor* as a lieutenant and the frigates *Turk* and *Arab* as a post captain. Ill health forced his retirement in 1805 and his entire service was spent in the West Indies.

[166] Robson, 1, notes that Cook was the second son of an itinerant farm laborer. He adds, 3, 14-19, that he went to sea on ships hauling coal from the north country to London at the age of seventeen, impressed the owning Walker family, was promoted to mate after several years afloat, and was about to be promoted to master (commander) of a collier when he volunteered for the Navy at the beginning of the Seven Years' War in 1755. He entered as an able seamen (above the ratings of ordinary seamen and landsman) due to his experience and within a month was promoted to master's mate (a junior warrant officer) aboard a 4th rate ship of the line, HMS *Eagle.* After two years of distinguished service in the Western Squadron, several single ship actions, and command of prizes and a cutter, Cook sat for the master's exam at Trinity house and was rated master (the senior ship warrant officer in charge of navigation and operating the ship) and assigned to the frigate HMS *Solebay* (a 6th rate)(pg. 40-41). He was quickly promoted to become master of the 4th rate ship of the line, HMS *Pembroke*, and headed to Canada to participate in the British victories at Fort Louisbourg and at Quebec. Cook's hydrographic contributions to Wolfe's famous victory which secured North America were noteworthy. Cook, promoted to the 3rd rate flagship *Northumberland* (pg. 94) served the remainder of the war in Halifax where he enhanced his surveying skills and attracted the attention of the local commanders, who secured for him the position of Surveyor of Newfoundland after the war.

clock and payment for labor time, not for a product. The new leaders of these operations were not just assembling the largest workforces in Europe, but they were administering the expense of vast sums of money, and managing natural resources on a global scale.

The Tudor Navy Royal was a semi-piratical medieval organization that established the foundations for a durable great power navy. The Royal Navy of the eighteenth century inherited two hundred years of tradition and forged the world's first truly global modern organization. That organization would dominate the world's oceans through the nineteenth century and into the twentieth. It would eradicate piracy and forcibly end the Atlantic slave trade that was so essential to its earliest forebears. It would make peaceable global trade possible and end the age of the heavily armed merchantman. Its cultural offspring, the United States Navy, would carry that torch to the present and continue to secure the world's sea lanes for the global trade of such intimate concern to England's first ocean mariners.

CHAPTER 10: CONCLUSION.
Multi-causal, Non-linear, and Interactive Social Development: Oceanic Conquest and the Birth of Modernity in England

The Age of Sail and the exploration of the oceans and the emergence of modern states and societies in Europe were roughly contemporaneous events. It has been the task of this work to examine the reciprocal influence each of these monumental events had upon each other. The particular focus of this work, after due regard is paid to Italian and Iberian paternity, is to examine the concomitant evolution of both in England from the Tudor to Georgian periods. This period takes us from England's first tentative steps at Atlantic exploration, into its Spanish tutelage and conflict, through its convulsive seventeenth political upheavals and Dutch merchant wars, and finally to its assertion of global maritime hegemony in its long series of colonial wars with France in the eighteenth century. This is the period over which the medieval kingdom of England evolved into imperial Great Britain on the cusp of the Industrial Revolution and the Modern Age. This work has sought to enrich the historical canon by moving the Atlantic maritime adventure from the background in the English modernizing story to a more central position. Although we end our review on the eve of the French and American Revolutions, and a cascade of ensuing modernization, the wide array of reciprocal societal impacts of the maritime project on the emerging British modern state and its society were by that time well established and in motion.

We have sought to narrow our definition of the modern nation state – centrally organized and secretive; bureaucratically controlled; invested in scientific progress for economic and political aggrandizement; capitalist; technologically dependent and adaptable; and industrial in both economics and war – and have claimed that it and its society were in part products and sources of European dominance at sea. The temporal scope of such an examination has by necessity been broad; we therefore have narrowed its specific target to that nation which most fully embraced the sea in its national mythology, and the one which introduced more of its novel institutions and economic and political theories to a larger part of the world than any predecessor.

The story of Western Europe's oceanic adventure, and therefore England's, like that of modernity begins in Renaissance Italy, and specifically with the merchant and banking principalities of Florence, Genoa, and Venice. Their role in the emerging maritime technology, finance, and maritime trade capabilities that were absorbed by Iberia and mixed with both local and North Atlantic maritime traditions is well documented and critical for completing a holistic story of the European conquest of the oceans. Understanding Europe's position in the fourteenth century and its comparative backwardness is also important when assessing the dramatic impact of their maritime achievement. But it is in Portugal and Spain that the Atlantic adventure truly starts.

In the Portuguese nautical program we see the early emergence of one of the quintessential modern mores of governance: specifically, the targeting of scientific research to enhance the prosperity of the state. We have observed how their scientific and nautical research projects interfaced with the product of the early Copernicans and how the data generated by the former helped buttress the epistemological position of the later. The evolving Iberian nautical programs and exploration and the dawn of the natural sciences were also contemporaneous events. Neither event happened in a vacuum. The modern world we live in, wedded to science and its pronouncements, was born in this period. The maritime forays of the Portuguese and the Spanish were as responsible for this as the mathematical purity of Copernicus and Kepler or the observations of Tycho Brahe. This evolving oceanic project and its geographic discoveries and conquests was born in Iberia and eventually brought to fruition by Castilian Spain. This successful exploitation of maritime technology, navigational science, daring exploration, imperial conquest, and sate sponsored applied science delivered vast wealth and power to the Spanish Crown, but it also attracted the jealously of her northern neighbors.

In order to manage its huge overseas holdings and the maritime program that sustained them, Spain created many proto-modern bureaucratic institutions and within its new Hapsburg empire, many novel methods of propaganda and state secrecy which have become emblematic of the modern world. We observed the emergence of large complex Iberian maritime bureaucracies designed to centrally manage all aspects of the emerging oceanic trade, the development of printed propaganda as a weapon of war and for swaying public opinion, and lastly the systematizing of complex technological endeavors for the use of men of little education for the directed purpose of state and corporate interests. But it is the activities of Spain's northern rivals upon which we have focused our attention.

A monumental development stemming from Hapsburg hegemony on the continent and in the Atlantic was the unfettered and aggressive use of private capital for national aggrandizement by the new Dutch state. Capitalism, one of the defining institutions of the modern world, witnessed its emergence from the feudal and mercantile world of Italian city states and kingdoms on the continent, and due to the men leading the oceanic trade consortiums, developed into the first joint-stock companies of the English and Dutch. Private capital, albeit with varying degrees of government sanction and favoritism, was diversifying the breadth of society involved in the maritime project. The challenge of Dutch, Breton, and English maritime interests to Spain, buttressed at home by the growing social influence of the maritime and merchant classes was to bring a seaborne component to the great sectarian clashes in late sixteenth and early seventeenth century Western Europe.

Ironically this clash between Catholic Spain and the Protestant north reached its apogee with Tudor England. Although Henry VII had been an early advocate of Atlantic discovery, England extensively had dropped out of period of early exploration in the fifteenth and early sixteenth centuries. Like the fifteenth century Ming dynasty half a world away, they rejected any leading role in maritime affairs and turned inwards, convulsed in civil and dynastic affairs. However, unlike the Ming, the English, or more specifically a small community of entrepreneurial London merchants and West Country pirates, supported by important privy counselors, pushed English society back towards the sea. Taking advantage of a brief period of rapprochement with the Hapsburgs during the rule of Queen Mary they wholeheartedly embraced their Spanish tutor. England's maritime community learned quickly and in the course of building up their capacity laid the foundation for many of England's lasting institutions. Of particular note is the joint-stock venture the Muscovy Company which introduced limited liability, diversified risk, and private financing to the emerging government chartered mercantilist monopolies which would eventually lead to modern capitalism. More significantly, risk sharing investments and the codification and simplification of Spanish navigation practice during this period was expanding the breadth of the maritime community at both its upper and lower ends. The expansion of this community was self-reinforcing. As it generated wealth and attracted participants, it grew and so did its influence upon policy makers, who in return structured policy to meet its demands creating yet more wealth and larger participation.

Mariners and their privy councilor investors and champions argued that England's security and eventual political ascendance could only come from control of the sea. In turn they subordinated their early oceanic program to political and security interests. Lacking large government bureaucracies, armies and navies (and the resources to support them), having a monarch with an abject hatred of debt and little tolerance for taxation, and possessing an independent trading class not easily shackled, the English chose to rely on security and secrecy institutions in their quest to first emulate the cutting edge oceanic programs of the day and later to protect the fruits of their own exceptional program. We observe in Elizabeth's England the decision by its early state makers to support scientific advancement to propel the fortunes of its maritime class while at the same time using the coercive power of the state to restrict access to the fruits of these discoveries. England's growing maritime community increased its influence on the state at the same time as the state was increasing its power. Having absorbed all it could from Spain, it was in open conflict with Phillip by the end of the sixteenth century in what appeared to be, to many militant Protestants, an existential struggle.

England and her mariners stood alone with only the rebellious Dutch as allies. As we saw in Chapter 6, victory at sea was produced by the cultures where an ascendant maritime community convinced the state that its interests were essential to national survival and aggrandizement. The English and Dutch accepted and encouraged the social turmoil inherent in the rise of this new social force, the Spanish resolutely did not. They expanded and grew their nautical canon up to a point, but superimposed over it a rigid aristocratic control at sea and ashore. As a result their maritime endeavor, their metropole control structures, and their empire ossified. The upstarts embraced their maritime communities, elevated their interests, succored their ambitions, and as a result surpassed their erstwhile tutors and overlords at sea and in the budding natural sciences.

The ensuing Hapsburg naval power vacuum, spectacular Dutch economic success, and civil discord in England, would precipitate conflict between the Protestant allies throughout the seventeenth century. However, the eventual ascendance of English maritime interests over the Dutch, the copious imitation of their financial institutions, and English internal struggles to institutionalize their national support for a standing merchant marine and navy of the first order, would reshape English society and enshrine the maritime community and its institutions as the leaders on its modernizing path. The Dutch and English aggressively pushed back the frontiers of knowledge in mathematics, navigation, cartography, ship design, ballistics, gunnery, foundry technology, blue water sailing, dry dock and shipyard management, instrument manufacture and innovation, and naval tactics. Late Tudor and early Stewart England focused its greatest intellectual minds and universities on resolving maritime issues. Mathematics success at sea helped embed our modern epistemology whereby quantification provides the absolute arbiter of truth. Maritime necessities also spurred investigation and data collection helping cement first Copernican math, and eventually heliocentric cosmology.

Maritime innovations also changed the social importance of labor trades that had been dominated by craftsmen whose status in the medieval social hierarchy were low. This evolution from medieval craftsman to modern professional was in part promulgated by Tudor and Stewart ship builders. With Mathew Baker, the Petts, and men like them, we see the introduction of mathematized drawings, scalable models, and eventually ships built in classes. As a result we witness the emergence of the ship designer. These designers ran large ship building concerns, garnered the support of wealthy and prominent patrons, and in England often had the ear of kings. This nation that relied upon its ‘wooden walls’ for defense and prosperity could not afford to denigrate the men that put those walls to sea. Quite the reverse, we see the emergence of a new social creation, again heralding the rise of the middle class, the design professional regarded for his technical skill and organizational prowess as well as his craftsmanship and economy.

These men did not need to physically supervise the assembly of their ships, but could delegate through drawings and standardization. Just as the new mathematical tool of logarithms was used to aid navigation, similar tools were developed to aid in ship design and timber allocation. Again we glimpse the modern default towards mathematics as arbiter of fact. As we have noted, these technically prompted social changes were not limited to England. As their naval power grew, the French responded in kind. Although France never could boast the long-term steady commitment to maritime prominence of her cross-Channel rival, she did have periods of furious naval accomplishment, especially under the direction of Louis XIV's Colbert. Under his supervision we observe the evolving professionalization and rise of new middle class engineers required by the state. Like their contemporaries in the navigation, they produced training curriculum and scientific results 'black boxed' for use by less educated functionaries. By 1765 France had militarized its construction corps, elevated its chief constructors into the petty nobility and set the standard for institutionalization which would be adapted by navies throughout the West.[1] In addition to these enduring institutional legacies, they developed mathematical ship building theories which were well ahead of their time and usefulness.[2] These theories would be adopted by England's Victorian ship builders of the early Age of Steam, but let us return to sailing.

[1] Ferreiro, 290.
[2] Ibid, 187, notes that of the scientific design theories developed in the period, only Bouguer's metacenter (the initial measure of ship stability measured as an imaginary point in relation to the ship's center of gravity) survives in today's design process.

Equally as important during this period, the Dutch and English developed proto-modern administrative bureaucracies to field these enormous naval and trading fleets. They developed financial institutions that created the enormous liquidity for both naval warfare and sustained global trade. They also pioneered devices for managing risk, diversifying losses, and mobilizing yet more capital as success overseas produced an upward spiral of ambition and productivity. And most significantly, the maritime trade classes, neither landed aristocracy nor peasants nor craftsmen, moved to occupy a position of central importance in both the Dutch Republic and the various English governments of the century. The modern middle class owes a good deal of its paternity to Dutch and English mariners.

At the same time England was institutionalizing modern science and applying much of its initial discoveries directly to the maritime program. The connection between England's maritime and intellectual communities was deep and growing. From the great universities of Cambridge and Oxford, to the new colleges like Gresham, to the Royal Society, great intellectual effort was committed to enhancing the nation's maritime skill. The state reciprocated by devoting resources which enhanced the growing prestige of natural philosophers and their pronouncements. The rise of science in the modern social milieu was to a large sense aided by mariners. In addition to the voyages of discovery of men like Halley and Cook discussed previously; the Royal Navy, Greenwich Observatory, and Royal Society would collaborate on such memorable voyages as Sir Joseph Banks' Brazil and Pacific exploration in Cook's HMS *Endeavor*, the ill-fated botanical voyage of 'Breadfruit' Bligh in the *Bounty*, George Vancouver's Pacific Northwest exploration, and Charles Darwin's expedition to the Galapagos Islands in HMS *Beagle.*[3] By the dawn of the eighteenth century the maritime endeavor was an

[3] Sir Joseph Banks was president of the Royal Society for 41 years and a distinguished botanist who was responsible for creating the Kew botanical gardens with King George III. He sailed to Newfoundland and Labrador in 1766

enormous undertaking and an integrated economic, intellectual, and social milieu that dwarfed the entire economic and intellectual output of medieval England. The English world had changed and it had changed at sea.

We have examined the growth of the English maritime community over these three centuries, to include its merchants, sailors, explorers, and pirates. We have observed the growth of the large land based support institutions and communities required to keep enormous fishing, merchant, and piratical fleets afloat and out deep into the world's oceans to include mathematicians, astronomers, financiers, insurers, shipwrights, cartographers, hydrographers, instrument makers, meteorologists, foresters, and intelligencers. Entire sub-economies and trade routes were required for timber, rope-making, pitch-production, block-construction, and sail-making. Provisioning ships and preserving stores were enormous seasonal operations that siphoned off any excess the agricultural and fishing communities could produce, and required cottage industries in salt production and barrel making. Arming the vessels spurred the growth of England's nascent iron and foundry industries, while accelerating alchemy into a chemical industry capable of refining the quality and supplying vast quantities of gunpowder. The growth of England's maritime ambitions spurred the growth of a maritime micro-economy into an integrated and complex economic system that in time became the predominant economic system of first England and then its successor, the United Kingdom. The growth of this economic and

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aboard HMS Niger and documented their flora and fauna using the new system of Linnaeus. He travelled on Cook's first Pacific exploration to observe the transit of Venus from 1768 to 1771. He was the leading inspiration behind colonizing New South Wales. He used his fame and connection with George III to sponsor more voyages of scientific discovery including Captain George Vancouver's Pacific Northwest exploration (1791-1795) which definitely concluded that there was no Northwest Passage at the latitudes hoped for. Under the auspices of the Royal Society in consortium with the Royal Navy, HMS (or HM Armed Vessel) *Bounty* was sent on a purely botanical mission to transplant breadfruit from Tahiti to the Caribbean at Bank's direction. Although the famous mutiny and acting Captain Bligh's remarkable feat of navigation resulted in failure, Bligh returned to Tahiti in HMS *Providence* (1791-1793) and completed Bank's initial charge.

Robson, 126, 167, 169, Cook was brought to the attention of the Royal Society when in 1767, John Bevis read his paper detailing Cook's very accurate observations of the 1766 solar eclipse from Newfoundland to the august body.

social milieu as we have seen was expanding in parallel with the evolution of the modern state in England and in many instances was causal.

The growth of the Royal Navy's bureaucracies in the eighteenth century presaged the direction of modern government. The increasing size, cost, and complexity of a standing navy in a large degree was the catalyst for the slow change from medieval courtiers to private contractors to technically competent career civil servants supported by an intricate network of private merchants as officers of state. We have also observed the evolution of a technically competent managerial class capable of piloting and commanding the enormously complex sailing systems of the age. This new social class of technically competent yet socially respectable leaders predates modern middle class managers. We also see in maritime affairs the growth of social welfare organizations and state control of natural resource management even on private land. Lastly, the Navy Board's dockyard organization was perhaps the world's first global business concern.

More important for our focus, the evolution of these dockyards and the groundbreaking patterns they established for the future industrialization of Britain's workers heavily influenced British society. It is not just that we see the beginning of work regulated by the clock and the diminishing of an individual's work into discrete interchangeable packages at the dockyards, but we also can observe the use of interchangeable parts at block mills and the beginning of assembly operations on a massive scale requiring an extensive logistics network that was often global. The eventual marriage of steam power and iron in the nineteenth century, pioneered first in Britain and quickly adopted in parts of Western Europe and the United States, and the rise of industrial capitalism dramatically changed established patterns of human life and threatened the stability of institutions developed over centuries. And although we do not claim a direct link from dockyards to the nineteenth British century textile industry, many leaders of British society and its economic life were deeply involved in the vast maritime logistics operations. The organizational and financial success and failures of this project had an impact upon Britain's future industrialists.

The tremendous surge in material prosperity ushered in by the Industrial Revolution, with all its concomitant social upheaval and institutional carnage, was not a phenomenon restricted to the land. The erratic, and often nationally idiosyncratic, introduction of steam and iron to the sea drew the curtain on the Age of Sail and accelerated the increase in global trade and interconnectedness of the nineteenth century Victorian world. This process of technological innovation and adaption at sea was not foreordained, it was not consistent in its national application, nor was it evenly spread within a nation's various seafaring entities. However, the pace of adoption of technology at sea, and the willingness of existing institutions to embrace its potentials and standard bearers, had enormous impacts on a nineteenth century nation's political power and economic growth.

We asked several questions regarding the maritime influence upon modern industrialization. Given that naval yards in both old and new worlds, from India to Philadelphia became the largest single employers of the age, did the enormous ship building enterprises of the late medieval Mediterranean and early modern period Atlantic powers presage modern industrialization? Did the exigencies of maritime power create the demand for facilities within these dockyards that could address the thoroughly modern demand for mass produced uniform interchangeable parts?[4] What we have observed is that the growth of the maritime project stimulated growth economically and organizationally, and it is logical to infer that reciprocal

[4] Similar demands upon land faced the armory complexes of Enlightenment and Revolutionary France and the Harpers Ferry and Springfield Armories of early nineteenth century America as addressed by Ken Alder and Merritt Roe Smith respectively.

influences between the maritime project and the evolution of the institutions of modernity tied to this economic and organizational development like Britain's industrialization process are valid. The mass production of textiles by steam driven looms in large factories would have been hard to imagine without the global supply network created by Britain's mariners, the excess capital created by its trade seeking investment opportunities, nor without its naval and merchant fleets on hand to protect and deliver that product to far flung consumers.

To repeat the observation made in the last chapter, Jan Glete has noted that, "The role of navies in the state formation process has often been neglected to that of the armies."[5] This work has explored that contention and has expanded that naval focus to encompass not just the Royal Navy, but the entire English maritime project of the Age of Sail. In a similar vein, our comparative target looks beyond modern state formation to a larger look at multiple, but axiomatic institutions of modernity. However, the goal of this project is not to identify an *explanandum* and posit a unique *explanans* for its existence. This work acknowledges the complexity of institution development and hopes to offer another piece to a developing puzzle of interwoven and reciprocating parts. We posed the question if there was a *Modernity and the Spirit of the Sea* – piratical, fearless, opportunistic, entrepreneurial, vainglorious, pragmatic, and scientific – and if this spirit permeated both the state makers and sailors of the period and if it was shared and reinforcing. Of that we can safely assert the affirmative. The influences of the maritime community upon England's development into a centrally organized and secretive; bureaucratically controlled; scientific; capitalist; technologically dependent; and industrial state are manifest. Dating to at least Elizabeth's 'Sea Dogs', Englishmen embraced the sea and both they and their country were changed forever.

[5] Glete, 63.

Figure 10.1. ***The Fighting Temeraire* by J.M.W. Turner (1839).** This painting features the retirement of one of the great 98-gun ships of Nelson's Navy, a distinguished veteran of Trafalgar. Although Turner employed quite a few elements of artistic license, this piece is a fitting tribute to the close of the Age of Sail. HMS *Temeraire*, 'Saucy' to her crew, is being towed up the Thames to the breaker's yard at Rotherhithe, SE London, by a grungy steam powered paddle-wheel tug, as the sun sets on an era. The Age of Sail would give way to the iron and steam future that the Age did so much to make possible. Without detracting from the message or the art, the *Temeraire* had already been dismasted and denuded of her guns prior to her last journey. [6] She was actually towed by two tugs and of course, the sun would set ahead of you to the West if you traveled up the Thames. Regardless, the painting is a remarkable testament to the sunset of the Age of Sail.

[6] Egerton, Judy (1998), *National Gallery Catalogues (new series): The British School...*, 308-309. Image from Wikiart.org, https://www.wikiart.org/en/william-turner/the-fighting-temeraire-tugged-to-her-last-berth-to-be-broken-up.

LITERATURE REVIEW

The obvious linkages between early modern oceanic conquest and the rise of the great Western powers has long been a subject for scholarly inquiry. Maritime historians can perhaps be excused some of their hyperbole when they seat the creation of the modern world squarely and solely within the sphere of their parochial interest. Jan Glete takes a more theoretical and multi-causal view in his seminal treatise *Warfare at Sea, 1500-1650: Maritime Conflicts and the Transformation of Europe*, in which he notes that "Trade, state formation and the rise of and decline of various centers of economic and political power are related to the technical, strategical, tactical and organizational changes of warfare at sea."[1] He presents detailed theoretical cases for these relationships ranging from materialist to sociological. Where Glete's focus is primarily military, his observation of naval-state relationships and their reciprocal impacts provides an excellent starting point for assessing one aspect of the holistic maritime-modernity relationship.

This work draws its primary source information from a number of disparate sources including many national maritime museums, period ships, the *Collections from the Royal Society: The Early Letters and Classified Papers, 1660-1740*, Project Editor Paul Kessaris, the State Papers (SP), Public Records Office, Kew, U.K., State Papers on Line, Gale 2011, and from the Royal Society's *Philosophical Transactions*. It also relies heavily upon historically contemporary manuscripts and navigation manuals from Francis Bacon to Edward Wright presented in the bibliography and footnotes. However, it is the intent of this section to address the significance of the concepts and research of recent scholarship used by this author and incorporated herein.

[1] Glete, Jan, *Warfare at Sea, 1500-1650: Maritime Conflicts and the Transformation of Europe*, 3.

There are a number of scholarly books that help seat this study contextually and provide insight into issues and connections highlighted by this analysis. Joel Mokyr's *The Lever of Riches: Technological Creativity and Economic Progress,* and Kenneth Pomeranz's *The Great Divergence: China, Europe, and the Making of the Modern World Economy,* are two such works. Carlo M. Cipolla's *Guns, Sails and Empires: Technological Innovation and the Early Phases of European Expansion, 1400-1700,* provides insight into both the origin of and the devastating impact that European naval gun platforms had in the Early Modern period. In addition, Nicolás Wey Gómez, in his *The Tropics of Empire: Why Columbus Sailed South to the Indies (Transformations: Studies in the History of Science and Technology)*, provides an excellent epistemological review of pre-Columbian Scholastic Europe.

There is an extensive literature on early modern European navigation, but the authoritative source is still the mid-twentieth century corpus of Eva G. Taylor. She has also edited a manuscript from an early Muscovy Company arctic explorer and the author of England's first indigenous celestial navigation manual. William Bourne's, *A Regiment for the Sea and Other Writings on Navigation By William Bourne of Gravesend, a Gunner (c.1535-1582),* is an excellent distillation of the state of English apprenticeship toward its Spanish rival at the end of the sixteenth century. David Water's book on Elizabethan navigation is also valuable, as are John Law's works examining the Portuguese maritime project and the system they created to exert long distance control across the world's oceans.

Thomas Kuhn's *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought,* is highly informative when examining the astronomical-navigation relationships examined herein, as are Robert Westman's various works. However, the philosophical thoughts of Kuhn regarding science require some expostulation. Although briefly summarized in the Introduction, let me add some detail. Kuhn views normal science and its practioners primarily as puzzle solvers – these puzzles and the rules for solving them are imbedded in their specific paradigms. In contrast, 'exceptional science' comes about when a dominant paradigm fails to provide its adherents with predictable solutions to its puzzles or when paradigm shifts in other fields force new questions upon functioning paradigms that nevertheless cannot address these new revelations. The resultant communal crisis in confidence in the dominant paradigm results, not in a return to pre-paradigm diversity, but rather in the emergence of a new dominant theory or paradigm that after a period or turmoil gains the adherence of the community at large. This process of paradigm revolution and its concomitant communal gestalt changes has been a regular feature of Western science for four hundred years. Kuhn borrows from historians of politics and the arts to present "scientific development as a succession of tradition-bound periods punctuated by non-cumulative breaks."[2] Science is not additive, but dialectic.

Scientific progress, in the limited form that Kuhn is willing to accept the definition, comes from these revolutions, as they produce paradigms that are better suited to answering the salient questions of a new time and context. Kuhn does not see these paradigm shifts as a march toward objective truth or as the logical progressive Whig version of science presented in science text books. Rather, paradigm shifts often discard past 'knowns' and methods and develop field fundamentals from scratch. Scientific revolutions are born from paradigm crisis and end only after a new dominant paradigm that addresses the failures of the past is accepted as dogma. According to Kuhn, this process is repeated regularly in the scientific tradition and results not in closer approximations of objective truth, but rather in more articulate paradigms.

[2] Kuhn, *The Structure of Scientific Revolutions,* 208.

In contrast to Francis Bacon, Kuhn contends that normal science and the progress its adherents make in identifying the workings of nature is dependent upon both the scientist's education and indoctrination into a paradigm (adopting Idols of the Cave) and upon the language and definitions provided by the field (absorbing and using Idols of the Market-place). Where Bacon wanted the scientist to recognize and isolate these and other idols, Kuhn insists that these preconditions provide the scientist with the *only* suitable tools for normal scientific work. Kuhn contends that normal science searches for confirmations of its paradigm, not for Bacon's objective facts or Karl Popper's empirical falsifications. Kuhn in effect is rejecting the Baconian or scientific method as untenable or even as myth. As I noted in the Introduction, one does not have to embrace Kuhn's philosophy of a dialectic science in order to use a number of the intellectual tools he has developed. A good number of his analytical tools, especially those grounding scientists in their social milieu and rejecting a teleological narrative have informed this work. Rejecting scientific empiricism and its accretive nature may have some grounding in abstract theoretical physics, but not when assessing the maritime sciences.

Several larger histories provide an excellent framework for examining and comparing the *Iberian* and northern maritime projects. Fernand Braudel's *The Mediterranean and the Mediterranean World in the Age of Philip II* and John Elliot's *Empires of the Atlantic World: Britain and Spain in America, 1492-1830,* are both authoritative. Following Braudel, the recent scholarship in Atlantic History, although remiss in overlooking the early Indian Ocean voyages, does provide an antidote to the purely national histories written in the past and establishes a broader comparative framework that is essential. Sanjay Subrahmanyam addresses the Indian Ocean omissions in *The Career and Legend of Vasco Da Gama* and *The Portuguese Empire in Asia, 1500-1700: A Political and Economic History*. An author of significant value to this work combines both the 'world' histories of the Mediterranean of Braudel and the new Atlantic in collections like Jack P. Greene and Philip D. Morgan's *Atlantic History, A Critical Appraisal*.

Felipe Fernandez-Armesto's *Before Columbus: Exploration and Colonization from the Mediterranean to the Atlantic, 1229-1492* examines the deep seated Mediterranean roots of the *Iberian*-Italian Atlantic world. He also presents a thorough revisionist critique of the Henry the Navigator mythology. Fernandez-Armesto contends that the Iberian maritime empires were shaped by medieval Mediterranean practices, backed by Italian technical and financial assistance, and geographically situated for success. He sees this same combination of cultural-economic-geographic determinism at play in explaining the rise of the Dutch 200 years later and in explaining 'why not' France or Catalonia. Columbus' watershed journey had deep Mediterranean routes which were both prepared by the Italian humanist revival of the preceding centuries and were ready to be exploited by the evolving Iberian maritime kingdoms that had been incubating in the western Mediterranean and the newly created 'Atlantic Mediterranean'. Fernandez-Armesto makes a convincing case for the Atlantic world's surviving and visible Mediterranean paternity.

Although extensive literature exists regarding the oceanic projects of the early modern Atlantic states, there is very little literature discussing the role that state secrecy played in the unfolding of these projects and there is no literature discussing the explicit connections between the oceanic project and the emergence and development of modern state security apparatuses and institutions. The existing body of literature examines the European national maritime projects by focusing upon the history, geopolitics, sociology, mechanics, epistemology, economics, military implications, or technological developments involved in crossing the oceans and colonizing much of the world. Some of the newer scholarship, like that of John Law, takes a holistic network approach to examining the phenomenon and its general implications by connecting many of these elements and viewing the whole as an integrated system. But the connections between maritime projects, the science involved, and the emergence of embryonic state security apparatuses has not received more than cursory asides in tracts dedicated to other points. Cosmographic and nautical secrecy is discussed, but finding extensive literature or primary source material documenting institutional developments to procure or safeguard that which states deemed essential for wealth or power creation is difficult. The very nature of secrecy makes this almost axiomatic. Therefore, the method employed by this study was to canvas a broad range of subjects and documents in order to identify and assemble kernels of information that as a whole can shed some light on this early sixteenth century clash between the exigencies of the state and the then emerging intellectual disciplines we refer to today as the natural sciences.

Over the past several decades a group of historians have started to examine the connections between secrecy and early European science. These works analyze the classical origins of the divisions between knowledge, technology, and practice, and how secrecy regarding technology and craft skills has largely been the province of individual tradesmen and eventually medieval guilds. A selection of this scholarship is presented in the attached bibliography. These works focus on books of secrets, botany, medicine, alchemy and the growth of legal institutions designed to encourage inventors and researchers to divulge their secrets by providing commercial protection. However, in a recent study by Leong and Rankin, the editors note that they have not included chapters about secrecy in astronomy, cartography, geography, and navigation. They acknowledge that secrecy played a key role throughout the development of each and that more scholarship is needed in this area.[3] Also missing in these studies, with the

[3] Leong, Elaine and Alisha Rankin (editors), *Secrets and Knowledge in Medicine and Science, 1500-1800*, Introduction, 19.

exception of Kristie Macrakis's work, is an analysis of the early modern European state's role in circumscribing scientific and technological output and the emerging attention given to the impact of science and technology upon national security.

Several recent Iberian maritime historians have looked at particular aspects of the maritime project and national bureaucratic attempts to keep its product secret; their work is integral to this analysis. Maria Portuondo's *Secret Science: Spanish Cosmography and the New World* and her detailed analysis of sixteenth century Spanish attempts to safeguard their cosmographical canon have been invaluable. The many papers by Alison Sandman analyzing the conflict between metropolitan cosmographers and Spain's pilots and her insightful discernment between official secrecy policy and practice are both nuanced and instructive. This author has also had the opportunity to attend a lecture on Sandman's recent study of the seventeenth century cosmographical realignment in the *Casa de Contratación* necessitated by the arduous journey to the Philippines and the resulting rebalancing of tacit and theoretical knowledge which became essential. In addition, Sandman's paper co-authored with Eric Ash on Sebastian Cabot provides an excellent theoretical bridge to the state of navigational affairs in Tudor England.

In reviewing the Tudor period, Richard Hakluyt's contemporary *Voyages and Discoveries*: *The Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation,* although distinctly intended as both English panegyric and propaganda exhorting a new British imperial project, provides an essential glimpse into the mind of Elizabeth's Privy Council regarding the navigation and exploration story that they wished to be told. Their more candid views are also expressed in the State Papers, Public Records Office, Kew, U.K., now available online, through Gale as of 2011. Although the details of much of Walsingham's operations were never included in these documents, the importance of England's piratical war of attrition against Philip II at sea is manifest, as is the role of espionage in ascertaining nautical knowledge.

A number of espionage studies have been written about Walsingham, his contemporaries, and the emergence of modern state intelligence institutions. The works of Stephen Budiansky and Alan Haynes provide both analysis of the structure of Elizabethan intelligence apparatuses and several maritime links. Samuel Bawlf's *The Secret Voyages of Sir Francis Drake, 1577-1580*, provides an excellent case study in the relationship between state secrecy and one of Elizabeth's 'Sea Dogs' that is purposely omitted from Hakluyt and missing from Drake's surviving works. This relationship between pirate adventurers and the shaping of England's state interests is also explored in depth in Susan Ronald's, *The Pirate Queen: Queen Elizabeth I, Her Pirate Adventurers, and the Dawn of Empire.*

The first published proponent of this empire is shrouded in controversy, but recently has been the focus of scholarly revision. Shedding the occult and mystic references is often difficult in assessing Dr. John Dee's contributions to England's maritime project. Much maligned in his later life and in the centuries following his death, Charlotte Fell Smith attempted to sort slander from fact in her biography at the turn of the twentieth century. Richard Deacon took up Dee's case in 1968 and arrived at the conclusion that Dee was more than just a crank and a mystic, but an English intelligencer (spy) and controller of a personal intelligence network aimed primarily at the preservation of his sovereign, but focused to a large part on nautical issues. These concerns are evident in his own writings: *John Dee: Essential Readings, General and Rare Memorials pertaining to the Perfect Arte of Navigation,* and *The Private Diary of Dr. John Dee, and the Catalogue of His Library Manuscripts,* referenced herein. Recently, Robert Baldwin and

William H. Sherman have added to this examination. They both have written essays about Dee's nautical interests that highlight his contributions to English navigation.

Like navigation, naval architecture has its own extensive corpus. This author made extensive use of the work of John Francis Guilmartin, Angus Konstam, and Robert Gardiner. I also relied on excellent technical analyses like Lawrence V. Motts *The Development of the Rudder: A Technological Tale (Studies in Nautical Archaeology, No. 3)* and Larrie D. Ferreiro's *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600-1800.* In particular, Ferreiro's study of naval architecture centers upon the naval bureaucracies, national academies and scientists (both natural philosophers and mathematicians) which drove the creation and implementation of ship theory during the Scientific Revolution (1600-1800), and dovetails with the holistic approach attempted in this work. As a naval architect himself, he does an excellent job describing the technical aspects of the scientific development of French ship design and the intimate relationship between the leading scientific lights of the period and the French naval hierarchy. He also does an equally thorough job analyzing the social and institutional constructs that he contends were the real impetus behind centralizing and controlling naval ship building during the early modern period in Europe. Larrie does not limit his treatise to 'how' ship theory was created; he also explores 'why' continental Europeans, led by the French, systematized, centralized, and mathematized a ship building process that had served them well for centuries.

There is also a genre of history dedicated solely to the Royal Navy. N.A.M. Rodger's and Herman Arthur's books provide excellent background material on this subject. When examining the history of England's naval activities there is no more authoritative source than N.A.M. Rodger. Both of the first two books of a planned trilogy, *The Safeguard of the Sea: A*

Naval History of Britain, Vol. 1, *660-1649* and *The Command of the Ocean: A Naval History of Britain*, Vol. 2, *1649-1815,* were essential sources for this case study. Rodger presents the long story of England's fitful and intermittent embrace of sea power and its eventual and propitious adoption of a national maritime mythology which did not truly take substantive form until the sixteenth century. He notes England's long history of amphibious invasion (counting nine since the Norman Conquest) and concludes that the sea for island nations is neither a geographically determinative safeguard against hostile neighbors, nor is it an impetus for the societal embrace of maritime communities and their related technology.[4] He notes the long-term planning and commitment necessary to achieving maritime proficiency, a theme expounded on in this work. Like the Avis monarchs throughout the fifteenth century, the English eventually achieved lasting maritime results only after generational commitment at all levels of society and enormous resources had been committed. The contrast he presents with the intermittent commitment of various French and Spanish regimes, and their sporadic results in naval proficiency is telling. Rodgers concludes that raising armies required force; raising navies required consensus.[5] His detailed studies provide context with detailed social history sections following each of his operational and administrative chapters.

Rodgers observations and work emphasizes the need for a truly holistic and social study of maritime issues and technology as John Law also suggests in his paper "On Methods of Long Distance Control: Vessels, Navigation, and the Portuguese Route to India," for *The Centre for Science Studies.* Law notes that the study of the means to European ascension – naval architecture, navigational science, and ordnance production – has been left to technical specialists in maritime history. Law sees this as problematic, arguing that "it is not possible to

[4] Rodgers, Safeguard, 429.
[5] Ibid, 432.

understand this expansion unless the technological, the economic, the political, the social, and the natural are all seen as being interrelated."[6] Our presentation has attempted to follow the example and admonition of both these scholars in presenting the modernity maritime thesis.

In reviewing proto-industry and shipyards, several specialized studies standout. Frederic Chapman Lane's *Venetian Ships and Shipbuilders of the Renaissance* is the classic study of the Venetian Arsenal, although recent studies by Richard Crowley and Robert C. Davis have expanded upon his work. Jonathan Coad's, *The Portsmouth Block Mills: Bentham, Brunel and the start of the Royal Navy's Industrial Revolution* is one of a number of recent studies on Royal Navy facilities and their influence upon the forebears of Britain's Industrial revolution. All these specialized studies, when aggregated, illustrate a wide ranging reciprocal impact between modernity's industrial institutions and those of the contemporary maritime establishments.

Like modernity and the structures of the modern state, this work had many influences, only a few of which are addressed above. The maritime adventure which started with the Atlantic forays of the caravels was a huge endeavor whose impacts we are still feeling today. It was generated from myriad sources and had diverse social impacts, all of which require a very large corpus to capture. Simply put however, to fully understand the modern world, you have to look to the sea.

[6] Law, "On Methods of Long Distance Control," 2.

APPENDIX: MARITIME TERMINOLOGY & MEASURES

<u>Ship Types</u>

Bark	Also barque or barc. A sailing vessel with three or more masts having the fore- and mainmasts rigged square and the mizzen rigged fore-and-aft (lateen rigged). The RN used bark for uncategorized vessels. Cook's converted collier used on his first Pacific voyage was named HM Bark *Endeavour* (the RN already had a sloop HMS *Endeavor* in service).
Brig	Similar to a sloop (see below), but smaller with 4 to 14 guns.
Caravel	A descendent from early Portuguese Atlantic fishing boats (*caravela*) and the northern cog. It was a remarkably seaworthy sailing ship suited to coastal exploration and the wind conditions of the open Atlantic. The ship was small and had a shallow draft and could safely cruise uncharted coastal waters and river estuaries. It was equipped with the most innovative naval technologies of the fifteenth century world. It was built skeleton first (carvel built) with flush joined planking, it had a pintle-and-gudgeon sternpost rudder and boasted one to three masts, usually with lateen sails. It could mount one or more of the new cannon just entering maritime service and with its low freeboard could fire devastating volleys *ao lume do agua* (low at the waterline).
Carrack	A carrack was a three- or four-masted sailing ship developed in the 15th century by the Genoese for use in commerce. Carracks were ocean-going ships that were stable in heavy seas, and roomy enough to carry provisions for long voyages. They were usually square-rigged on the foremast and mainmast and lateen-rigged on the mizzenmast. They had a high rounded stern with large aftcastle, forecastle, and bowsprit at the stem. The workhorse of the *Carreira de India*, the Portuguese carrack performed the dual function of transport vessel and fighting ship. These 'Indiamen' were heavily armed merchant ships, and in their day, they were the largest vessels afloat (up to 2000 tons). Their high sided hulls and stern and forecastles which protected them in Asia made them vulnerable to improvements in gunnery by the end of sixteenth century that eventually displaced them. They were also top heavy and prone to wallowing which reduced their gunnery accuracy. With linguistic variation, these ships were often called: *caracca* or *nao* in the Genoese dialect and in Castilian Spanish; *nau* in Portuguese; *caraque* or *nef* in French; *kraak* in Dutch and Flemish.
Cog	North European trading vessel characterized by single square rigged mast and rounded hull; descendent of the knorr. It was clinker-built, had a pronounced stem and sternposts; was round and wide; and had a large sternpost mounted rudder. By the fifteenth century the hull was rounder, stem and sternpost were more curved, and with the addition of permanent castles (fore and aft) it was often converted into temporary warships (infantry platforms).
Collier	A cargo ship designed with a large hold to accommodate carrying coal

Frigate	A full rigged sailing ship which evolved out of the galley hull form by early seventeenth century Dunkirker pirates. They were lightly armed, heavily manned, and fast. They entered British service as cruisers and served as the eyes of fleet in Europe, as the nation's flag abroad, and as the mainstay in the very modern evolving economic warfare centered on the world's oceans. It filled the primary roles of both commerce raiding (*course de guerre*) and convoy protection. It could not serve in the line of battle but could perform all those functions the smaller sloops and brigs were unable to perform. In the Royal Navy, the ship was rated as fifth or six rate (depending on the number of guns – ranging from 20 to 44) and commanded by a post captain.
Galleasses	A large hybrid sailing ship with oars. It was created as an innovative response to the lack of maneuverability still extant in sixteenth century ship rigging technology and used to counter the galley. These ships proved decisive at Lepanto and were included in Henry VIII's ship building program of the mid-1540s. It was built low in the water galley fashion and powered by a full sailing rig or with oars which would project through oar holes below the gun deck.
Galley	A long tapered ship form largely propelled by banks of oars, housing one large square rigged mast for advantageous winds. It was the dominant Mediterranean war vessel from antiquity through the Renaissance clashes between the Venetian Republic and the Ottoman Empire. The early addition of bow mounted cannon made this vessel the most lethal warship afloat until improvements in sailing rig technology and the advent of the galleon gave sailing shups a dominant position.
Galleon	Most likely a hybrid creation of the Spanish with Venetian influences (early galleons were probably modeled off of Venetian *galleoni* – oars and sail hybrid), although Portuguese claims of paternity are not specious. The first galleons were small and combined both sails and oars, but these ships rapidly grew and lost their oars as the ship-type matured by the middle of the sixteenth century. The galleons primary distinction over the carracks of the period was their low narrow sleek hull and long low beak-like bow mounted with heavy ordnance. Where the carracks of the day were high walled with heavy castle structures fore and aft, and designed for infantry clashes, the first galleons were designed to fire on the attack while maneuvering toward an enemy like the galley. It also had a mixed sailing rig and would eventually grow into the ship of the line.
'Race-built' galleon	Purpose-built Elizabethan galleons combining speed, maneuverability, and firepower. They were prototypes of the ships of the line – heavily built and heavily gunned, built without the remaining stern castle of the Spanish galleon. They had a 3:1 beam ratio, double the amount of guns for ships their size, a single continuous gun-deck, and finally, pre-copper sheathing to combat teredo worm (*Teredo Navalis*) and dirty bottoms (which decreased speed).
Knorr	Scandinavian clinker built trading vessel with a lineage dating from the eighth century with a side mounted quarter rudder

Hulk/Nao	The 15th century replacement for the cog – it was larger and more seaworthy. The Nao was often a Iberian hulk. The hulk had same broad round hull shape as the cog and was good for both cargo and as an infantry platform. The Iberian shipwrights added a topsail to the tradition central single square rigged mast and possibly a lateen mizzen mast and bow sprit which helped with sailing closer to the wind.
Nao	Full rigged ships of early Portuguese and Castilian exploration and trading programs of the fifteenth and sixteenth centuries; a vessel very similar to the carrack and often used interchangeably by other authors to describe the larger high walled multi-purpose cargo/war ships of the day.
Nef	French evolution of a warship with fore and aft castles smaller than the carrack. It was a large French carvel-built version of the hulk (its only major descendant) with three rather than two masts.
Pinnace	A small and light sailing ship serving a larger ship as one of the ship's boats. It often had two or three masts and a flat stern. It was usually stowed aboard ships of the line, frigates, and galleons, or dissembled when not being used for inshore work. It could also be used as a warship or merchantman in its own right.
Ship of the Line	The enormous battle ships of the Age of Sail featured two to three main gun decks housing 64 to 120 guns, had three towering masts with three to four courses of sails each, and extraordinarily thick oak hulls up to two feet thick at the waterline. These floating artillery batteries were built to overwhelm their opponents throwing hundreds of pounds of metal in a single broadside and were built to take a similar pounding. They were the most complex machines of the eighteenth century. They required 600+ men to sail and fight the guns; tons of provisions, stores and water; and a technically competent leadership cadre. The first four rates comprised the line of battle until Anson reduced it to three.
Sloop of War	Unlike its civilian counterpart with a single mast and lateen rigging (a fore-and-aft mainsail and a jib), the navy sloop was ship-rigged on two masts (with up to three courses of square sails per mast with lateens or jibs rigged fore-and-aft from the foremast to the bowsprit). It was the largest unrated RN ship, carried 16 to 18 guns, and was commanded by a Master and Commander, nominally called captain.

Ship Components, Construction, Maintenance, and Stores

Aft	Towards the stern (rear) of the ship
Beam	Widest point of a ship, its side at about the center
Bluff	Rounded, flattened, and broad. Used to describe a non-aerodynamic or non-tapered shape of a ship's hull form; usually either the bow or the stern
Bow	The front of the ship

Bowsprit	A spar (a yard running fore-and-aft) extending at an inclined angle forward from the bow, to which the forestays are fastened
Careening	A hull cleaning and repair process conducted afloat and which required heeling the ship to expose one side of the hull at a time.
Carvel construction	Hull construction method developed in Portugal for its caravels where the hull skeleton is built first and flush joined planking is added. The benefit of the skeleton framing technique was the flexibility it provided shipwrights in buttressing the hull when they started adding a new innovation – naval cannon.
Cloveboard	A board split rather than sawn into planks
Clinker construction	Hull construction method of Northern Europe used by the Norse and on Hanseatic Cogs, where the hull was built with overlapping planks. In this method the shell of the hull is built first and reinforcing beams are added later.
Cordage	The ropes, sheets, and cords used to rig a ship
Dry Dock	A narrow basin or slip that allows a ship to enter and which can be drained after the dock doors or bulkheads are closed and sealed. Used for repair and construction.
Freeboard	The height above the waterline to the main deck of a ship
Foremast	The mast nearest the bow in all vessels having two or more masts
Fore-and-aft rigging	Sails running parallel with the length of a ship; usually lateen sails - jibs from foremast to bowsprit, or rearward from the mizzen, or stays'ls between the masts
Fore	Toward the front of the ship
Fo'c'sle (forecastle)	The structure above waterline at the ship's bow on the upper deck – a remnant of the castle structures assembled forward on medieval cogs and carracks
Graving	A hull cleaning and repair process conducted by beaching ships at low water to repair their hulls
Gun deck	One of the main decks that carried the ship's broadside cannon below the upper deck on a ship of the line. Also where the crew berthed and messed.
Hemp	Northern fiber often mixed with pine pitch to caulk a ship's hull and decking
Lateen sail	Latin-rigged triangular sails hung diagonally along the line of the ship's length which enabled a ship to sail closer to the wind using the principles of an airfoil
Mainmast	The largest and primary mast of a ship, typically the second mast in a sailing ship of three or more masts – often comprised of multiple spars

Mast	A long spar seated on the keel or deck of a ship which supports the yards, staysails, jibs, and rigging
Mizzenmast	The mast aft (to the rear) of the mainmast
Mud Docks	A dry area used in the Middle Ages to repair ships either on shore, beached at high or spring tide, or in an excavated inlet, protected by a watertight earthen dockhead. These mud docks required immense amounts of labor to excavate for large ships, more labor was required for launching, and they required extensive draining and reconstruction for multiple uses.
Pintle-and-gudgeon	The hinging mechanism on sternpost-mounted rudders (the pintle is a pin and the gudgeon is the socket). This innovative northern steering mechanism was itself a blending of technologies including the wrought iron hinge, the stern mounted rudder and the straight stern post.
Pitch	Boiled and concentrated tar applied to the sides and bottoms of wooden ships to make them watertight. It was used as caulking when solid and heated for painting.
Quarterdeck	The part of a weather deck that runs aft from the mainmast to the stern of a vessel. On larger vessels it was a raised deck. The captain commanded, the master conned, and the quartermasters steered the ship from this location. It was often the preserve of commissioned and warrant officers unless duty called a seaman to its location. On a large ship it would stop at the foot of the poop deck.
Rudder	The steering mechanism on a ship, usually mounted on the sternpost or the rear quarter
Ship-rigged	A full-rigged ship and by definition a ship due to its rigging. Full-rigging included at least three square-rigged masts of multiple courses and could include jibs, staysails, and mizzen lateens.
Spar	A thick, strong tree trunk used for a mast or yard on a ship
Square-rigged	Large square sails hung on a yard attached to a mast that captured a following wind or one off the rear quarters
Stays'l (staysail)	Triangular sails rigged fore-and-aft between the masts used to sail on a bowline or closer up to the wind
Stern	The rear of the ship
Sternpost	The squared off central upright beam at the rear of the ship rising from the keep onto which the rudder was normally mounted
Tar	A sticky liquid produced by burning pine branches and logs very slowly in kilns. It was used to coat the rigging that held masts and sails in place.
Victualing	Providing foodstuffs for an ocean voyage

Weather deck	The upper deck of a ship open to the elements
Yard	A long spar mounted to a mast which supports a sail

Naval Stategic and Tactical Expressions

Line-ahead tactics	The standard formation of line of battle where ships sailed bow to stern in a single line to provide each other mutual support at their vulnerable bows and sterns and to mass their broadside firepower against enemy formations sailing in a parallel or opposite direction.
Line-abreast tactics	Sailing side by side and travelling bow onward toward the enemy perpendicular to his motion.
Course de guerre	The national naval strategy privileging commerce raiding – from war of the chase
Guerre d'escadre	The national naval strategy privileging battle fleet action, blockade, and controlling the sea lines of communication by sea power
Van or vanguard	The lead ship or division in a squadron or fleet movement
En flute	Warships stripped to serve as transports
Flota	The Spanish convoy system used to supply its American colonials and to protect the return of its specie to Seville.
Muda	Venetian galley convoy system designed to provide mutual support and protection in the Mediterranean
Weather gauge	The position in battle upwind from the enemy which gave its possessor the ability to force action or decline action

Astronomy, Cartography, Navigational Instruments and Expressions

Altura	The height above the horizon, of the sun or a star (normally the Pole Star)
Astrolabe	An elaborate inclinometer with a round marked disk and a cross piece (see Chapter 3, page 79). The Mariner's astrolabe was developed from the astronomer's terrestrial and more complicated ancestor, specifically for pilots measuring the altitude of celestial bodies at specific designated times, by the Portuguese metropolitan cosmographers.
Back-staff	See Davis Quadrant below
Cartography	The art of making maps

Compass point	One of thirty-two compass rose segment used by Tudor mariners – each point was 11-¼ degrees (see Chapter 6, page 203)
Cosmography	A holistic blend of geography, cartography, ethnography, natural history, history, and astronomy which was prevalent in Renaissance and Early Modern Europe
Cross-staff	A graduated stick with a cross piece used to gage celestial inclination above the horizon (see Chapter 3, page 80)
Davis Quadrant	A device designed to avoid solar glare by requiring the observer to read shadow and horizon, rather than ascertaining solar height by staring directly at the sun while simultaneously fixing the horizon. It became the standard instrument for taking celestial observations for over a century and was only replaced by the widespread use of the sextant in the eighteenth century.
Dead Reckoning	From Deduced, or as abbreviated 'D'ed', Reckoning (see footnote 69, Chapter 7) – The system of estimating a ship's position by estimating the distance travelled from a known point by an amalgam speed, current, drift, leeward wind pressure
Declination	Magnetic declination or compass variation is the angle between magnetic north and true north. Declination varies and is a local and temporal phenomenon.
Doldrums or variables	The Intertropical Convergence Zone, is a low-pressure area created by the convergence of the wind systems north and south of the equator. It is where the trade winds meet between approximately latitudes 5° north and south. The area is often becalmed and stranded sailing ships motionless for days or even weeks.
Ephemerides	Astronomical tables identifying solar and stellar position on a given day with declination (see Chapter 4, page 109)
Gunter Scale	When coupled with dividers, this predecessor to the slide-rule allowed seventeenth century mariners to quickly 'read' trigonometric quantities essential to global navigation without laborious mathematical calculation or resorting to tables (see Chapter 7, page 245)
Gyre	The North Atlantic Gyre features a clockwise rotation of current and wind off shore. In the South Atlantic, the South Atlantic Gyre rotates counter-clockwise and required a westerly course to almost Brazil for outbound Indiamen. Similar gyres exist in the Pacific and were essential for Spain's Philippine Galleon.
Hydrography	A holistic blend of navigation, astronomy, surveying, and cartography directed at measuring and charting the physical features of oceans, coasts, and estuaries (including the prediction of their change over time) to aid safety of navigation.
Hydrology	The science which studies the movement and physical qualities of water
Inclination	Compass inclination or magnetic dip (the incline at an angle from the horizon caused by the Earth's magnetic field not running parallel to the planet's surface)

Latitude	The angular measurement of a point north or south of the equator – lines of latitude climb from the equator (0º) to the poles (90º) decreasing in length as one leave the equator and are always parallel to one another
Logarithm	From the Greek words *logos* (proportion or ratio), and *arithmos* (number) – a ratio calculation whereby the exponent indicates the power to which a base number is raised to produce a given number
Longitude	An angular measurement of distance east or west of the prime meridian centered on Greenwich, England – lines of longitude run from pole to pole (where they converge) and have their widest separation distance at the equator.
Lodestone	A naturally magnetized piece of the mineral magnetite which can attract iron. The name lodestone in Middle English means 'course stone' or 'leading stone' from the obsolete meaning of lode as 'journey' or 'way'.
Magnetic Dip	See Inclination above
Magnetic variation	Compass needle declination or deviation from true north (inclination references magnetic dip; declination compass variation) – See Declination above
Meridional parts	Parts of the meridian in Mercator's projection, corresponding to each minute of latitude from the equator up to 70 or 80 degrees
Meridian	A circle line of longitude around the globe
Nautical triangles	Also referred to as Navigational Triangles. The spherical (or celestial) triangle solved in computing altitude and azimuth or great-circle problems.
Octant	A reflecting device with an angle measuring range of ninety degrees (the "A" frame of the device itself was open to forty-five degrees or one eight of a circle, from Latin *octāns*). It was designed to measure the altitude of the sun or other celestial objects above the horizon at sea. (see Chapter 8, page 329)
Parallax	The dislocation an observer of an object perceives based on different observation locations – measured as an angle of inclination
Portolan Chart	From *portolani* , or pilot books of Mediterranean sailors; they were inscribed with straight line sailing directions which converged at assorted compass roses. They lacked latitude or longitude lines and covered relatively small global distances.
Rhumb lines	A rhumb line, rhumb, or loxodrome is an arc crossing all meridians of longitude at the same angle – a path with constant bearing as measured relative to true or magnetic north.

Rutter	A mariner's handbook of written sailing directions. Before the advent of nautical charts, rutters were the primary record of geographic information for maritime navigation. It was known as a *periplus* ('sailing-around' book) in Classical antiquity and a *portolano* ('port book') to Medieval Italian sailors in the Mediterranean Sea. Portuguese navigators of the 16th century called it a *roteiro*, the French a *routier*, from which the English word 'rutter' is derived. In Dutch, it was called a *leeskarte* ('reading chart') and in German a *Seebuch* ('sea book').
Sextant	An improved Octant (see above) and the standard navigation instrument at sea from the middle of the eighteenth century until the advent of radio navigation. It had a slightly larger arc of measurement (the sextant of one hundred and twenty degrees, with a frame angle of sixty degrees or one sixth of a circle) which more easily enabled lunar and stellar observations. (see Chapter 8, page 330)
Trade winds	The regular easterly winds the tropics and subtropics which blow from the northeast in the Northern Hemisphere, and from the southeast in the Southern Hemisphere. Edmund Halley in his 1686 Map of the Global Trade Winds depicts the major reversal of the trade winds between the winter and summer monsoons of Asia and Australia (see Chapter 8, page 324)
Triangulation	Originally a land surveying method, it uses the measurement of the angles in a triangle formed by three survey control points, trigonometry, and the measured length of just one triangle side to calculate the lengths of the other triangle sides.

Maritime Personnel

Able Seaman	A position created after 1653 to recognize and reward experienced seamen who could "hand, reef, and steer." These sailors were paid about 25% more than an ordinary seaman and had a higher prize share. In full the position was Able Bodied Seamen and abbreviated AB.
Admiral	Traditional flag rank of the Royal Navy originally there were three admirals, vice admirals and rear admirals of the red, white, and blue squadrons denoted both their seniority and the squadron they led in the line of battle.
Boatswain or boson	One of the standing officers of the ship who directed the labors of sailors aboard ship in regard to rigging, anchors, and cables;
Butescarli	Early name of sea-officers in the English navy
Commissioned Officer	Rank issued by the Commissioners of Admiralty
Landsman	Often pressed sailors with no seagoing experience of little use other than hauling on a rope
Lieutenant	Commissioned officers responsible for assisting the captain, taking a watch, and running a division afloat. Senior lieutenants often commanded smaller ships like cutters or transports.

Master and Commander	A junior captain promoted to command a sloop or a brig.
Master	The commander and often the owner of merchant vessels. In the Royal Navy, he was the senior warrant officer responsible for navigation and the daily operation of the ship and direction of its other warrant officers
Master Gunner	One of the standing officers of the ship responsible for the guns and powder
Master's Mate	Assisted the master in running the ship, navigating, and plotting the ship's course
Ordinary Seaman	A seamen with one to two years' experience afloat
Petty Officers	The junior officers of the ship including midshipmen (master's mates excepted as they were junior warrant officers) and most of the specialists assisting the Standing Officers, the Purser, and the Master. The Armorer, Ropemaker, Caulker, Sailmaker, and Master at Arms also received their warrants from the Navy Board.
Post Captain	A captain on the seniority list entitled to command a rated ship of the the first through sixth rate.
Purser	Warrant Officer responsible for stores, feeding and paying the sailors
Quartermaster	Helmsmen, they assisted the master of the vessel by steering the ship – usually from the quarter deck. Quartermasters were Petty officers.
Ratings	Refers to the ranks of the RN, but more commonly used to refer the sailors
Standing Officers	The gunner, boatswain, and carpenter who were non-wardroom warrant officers, but as specialized stayed with the ship even when it was in dock for repairs
Tarpaulin	Originally the experienced common born merchant mariners (often masters) of the seventeenth century RN aligned with Protestantism and trade; the term evolved in the eighteenth century to also include RN officers who started as ratings or warrant officers and through their own ability and often with the patronage of seniors, became commissioned officers.
Warrant Officer	Technically competent officers whose warrant was issued from the Navy Board. They included the Master, the Purser, the Surgeon (whose warrant came from the Sick and Hurt Board), the Gunner, the Carpenter, and the Boatswain.

Nautical Terms and Measures

Cable	120 fathoms or 720 feet
Degree of meridian	Sixty nautical miles (nm)
Fathom	Six feet; derived from the span of a sailor's opened arms

Knot	One nautical mile (nm) per hour; English sailors, regularly threw a log tethered to a line knotted at regular intervals and compared the number of knots played out to a time regulated by a small sand glass
League	A very flexible measure depending on nationality and time period ranging from two to six miles. The British used three nautical miles (3.452 miles).
Leeward	Downwind – pronounced 'lou 'ard'
Lubberly	Lacking in seamanship; of or suitable to a landlubber who is new to being at sea and unfamiliar with the ways of a sailor; or an 'unweatherly ship or craft'
Luff up	To ease a ship towards the direction of the wind
Minute of meridian	One nautical mile (nm)
Nautical Mile (nm)	A nautical mile is now calibrated as 1.1508 miles, or 6,076 feet. One nautical mile (nm) represents one minute of a degree of latitude, sixty nm equals one degree of latitude.
Tack	Turning the bow of a vessel through the oncoming wind to change direction
Tonnage	Customary measure of a ships size which has evolved from the Middle Ages. The initial measure from the period gauged the vessel's cargo carrying capacity measured in 'tuns' or wine casks holding 252 modern gallons. By the sixteenth century this number was approximated by calculating internal volume. Today tonnage refers to the water displaced by the hull.
Weatherly	A boat or ship able to sail close to the wind without drifting too much to leeward
Windward	The side or direction from which the wind is blowing
Wear	Turning the bow of a vessel away from the oncoming wind to change direction

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